THE PROBLEM OF BRACKEN (PTERIS AQUILINA)

IN RELATION TO ANIMAL HEALTH.

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by

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List of Published Papers.

1) "A preliminary note on the Donnan Membrane Equilibrium between Egg-yolk and Egg-white and the effect of KCN Solution on it".

(N. M. Basu and A. K. Pal - Proc. Physiol. Soc. India Vol. 2. 1936) Abs. Indian Sc. Cong)

2) "The behaviour of RBC in Solutions of NaCl and $CaCl_2$ of different tonicity and a new theory of the structure of their envelope".

(N. M. Basu., A.K. Pal and others - Proc. Physiol. Soc. India. Vol. 2 1936. Abs. Ind. Sc. Cong.)

3) I "Studies on the composition of the Blood of Farm Animals in India".

1. "A study of some haematological and chemical Constituents in the Blood of Normal Cattle."

(D. N. Mullick and A.K.Pal - Indian Vet Science and Animal Husbandry, Vol. 13 P. 146-149. 1943).

4) II"Studies on the Composition of the Blood of Farm Animals in India".

11. "Seasonal variations in the Blood of Dairy Cattle".

(A.K.Pal., S.A. Momin and D.N. Mullick - Indian Vet. Science and Animal Husbandry. Vol. 15. page 119. 1945)

5) (An abstract of a paper on "Chemical Composition of Ghee from milk of different breeds of Dairy Cattle" appeared in "Proc. of Indian Science Congress - 1945 or 1946 - reference not available in Edinburgh)

(A report on "Vanaspati Scheme" -(6 to 7 papers)- may have been published during my absence from India).

C O N T E N T S .

Contents (con't)

Abreviationshave been used for Dry Matter, Crude Protein, Crude Fibre, Ether Extract and Nitrogen Free Extract throughout the tables in this thesis.

P R E F A C E .

The problem of bracken in relation to animal health is ill understood not only in this part of the world but also on the Continent, in the United States of America and in Australia. Time and again, attempts to solve the mystery were baffled in the face of inadequate data. It is also possible that the harmful effects of bracken or plants of the same species and genus, have escaped detection in many other parts of the world, when the cause of death in many cattle remained obscure.

The importance of the problem will perhaps be sufficiently apparent from the vast acreage ~~of~~ (more than 3 - 4 millions of hill-grazings in Scotland) being infested by bracken which is invading on fresh fronts, all over the country, every day.

For many years past, beginning from 1893, large numbers of cattle died from so-called "Bracken Poisoning". In certain years, specially in drought years, the mortality in cattle ~~population~~ caused considerable anxiety to farmers. "Bracken" was therefore considered generally by local farmers as a menace to stock. Yet, the controversial nature of the many aspects of the problem, will be evident from the brief review of the existing literature, an attempt to present which is made in the first part of this thesis.

The disease first noticed by its mysterious appear-

appearance in this country in 1893 by Penberthy has remained a mystery till the present day in view of the highly controversial nature of the problem and the lack of sufficient data. It was therefore thought essential to carry out systematic investigations into the cause of the disease mainly from nutritional and biochemical aspects.

CHAPTER - I

C H A P T E R I

Review of Literature .

A. History of Reported Cases

The first report of illness in cattle, possibly due to the consumption of bracken dates back to 1893 when Penberthy (23) noticed the prevalence of a mysterious disease in cattle on several farms in the county of Pembroke. He recorded 22 deaths in animals of various ages on Warren Farm, Pembroke. In a dairy farm 5 out of a total of 8 cows died. Two more animals died on another larger estate. That the question of contagion did not arise was suggested by the fact that on another farm, about 10 miles away One animal died and another was in a moribund condition. In Armoth, also in Pembroke county, 4 cows died and 1 recovered.

The drought of the spring and summer of the year had been very severe - one of the most notable of the century. Penberthy noticed that the majority of the cases occured sometime after rain, following a drought of severe intensity; that the cases were particularly restricted to grazings favourable for growths of ferns and:

and gorse and that the disease was specifically confined to bovines. The horses, pigs, swine and sheep grazing on the same place and apparently subjected to similar conditions did not take the disease. This last fact did not seem very unlikely to him as there appear in the literature, cases of vegetable poisoning, e.g. acorns, restricted to a certain species of animals, the bovines only. (24)

Penberthy also reports that he heard of similar serious losses of cattle from Surrey, Kent, Lincolnshire, West of England, Midlands and Ireland. An experimental feeding trial on one young bullock with bracken yielded negative results.

Storrar (25) mentions the incidence of a similar outbreak in cattle after an excessive drought, in the same year. On examination of the pasture, it was noticed that the young fronds of bracken ferns had been eaten off very closely. Fifteen head of cattle from the area were changed over to an aftermath where there were 10 other cattle. These cattle all grazed together. Curiously enough, all the cases he reported were confined to the 15 head placed on aftermath after being on a bracken-infested sward. Out of these 15, 8 cattle died, 3 or 4 had been affected and recovered and 3 bullocks showed no symptoms. This fact, he thought demonstrated:

demonstrated clearly that bracken was responsible for the malady. His case reports covered animals of both sexes, young and old, extending from ages of 1 year 9 months to a 5 year old dam with calf at foot.

Freeman (8) described an obscure disease in cattle from Ireland, in the same year. He failed to find any reference to such a peculiar disease in previous veterinary work and stated that the disease was somewhat similar to "purpura Variolosa" or "Variola haemorrhaegica" in human subjects, in course and symptoms, as described by Dr. Von Ziemessen of Munich in "Cyclopædia of the practice of medicine". He observed the incidence in the mountainous districts where grasses were coarse but of good feading value with quite a good water supply. He does not however, ascribe the disease to bracken. There was, in fact, no survey of pastures and hence no indication that bracken might have been responsible. He merely reported the incidence of this disease in Ireland. The similarity of the symptoms to those observed by Penberthy and Storrar and the incidence about the same period necessitated the inclusion of this disease under our present discussion.

The disease was, in most cases attributed to the presence of bracken in grazings, the balance of opinion from field-cases favouring this suspicion. The proofs of:

of this contention were soon forthcoming when, in the following year (1894) the editorial columns of the Journ. Path and Thera (1) reviewing the question of poisoning by fern (Bracken) referred to the outbreak the previous year as observed by Penberthy and the cases noted by Freeman in Ireland. It was pointed out that during unusual drought periods as experienced in 1893, the cattle were driven to eat bracken which was practically the only herbage in bare pastures and they later showed symptoms of the disease. The drought nearly burnt up the pasture in which only the ferns could survive. Though Penberthy recorded negative results in a feeding trial on a young bullock with bracken, the editorial revealed on the authority of Nicholson Almond, that this disease had been successfully reproduced by experimental feeding of bracken chopped up with straw and gradually withdrawing the latter until the diet was composed solely of bracken and turnips. No data however are given concerning the experiment.

Muller in Germany, has recorded illness in horses after prolonged feeding of bracken silage.(18) He however did not mention the proportion of bracken in the feed. His findings are somewhat contradictory to the findings recorded by Watson and mentioned by Tocher in his review.(31) The young bracken made into silage was found harmless by Watson when fed to stock.

For:

For some time, reports were available in the annual reports of the Board of Agriculture in this country, referring occassionally to a so-called "mysterious disease" in cattle. Almost in every occassion was this attributed to ingestion of bracken by cattle as this was found available to animals and was noticed to be browsed in most cases in such areas. (5) In 1909 and 1910, Stockman pointed out the seriousness of this mysterious illness of which several outbreaks were reported. These various outbreaks were almost exclusively during the Autumn - August to the beginning of November. McGowan (19) was of the opinion that the clinical syndrome was not due to a poison in bracken but was due to the bacillus of haemorrhaegic septicaemia which he claimed to have isolated from the blood of cattle dead from bracken poisoning. Stockman put forward a criticism that such organisms were normal post-mortem invaders and have nothing to do with the disease. Hagan (13) and Kerdiles (14) found no evidence to support McGowan. Later, in 1917, Stockman (26) conclusively proved for the first time, by experimental feeding that the fronds of bracken were poisonous to cattle when ingested, particularly during the months of August up to the beginning of November. He believes the mature fronds to be more toxic than the younger ones. It may be stated here, that there are considerable divergencies of opinion of this last point which will be apparent in the course of this review.

In 1917, Stockman first fed a heifer for 9 days on a total quantity of 56 lbs of bracken with a negative result. Another heifer, on 30 lb of bracken for the first 2 days followed by 6 lb a day for the next 5 days (total:

(total 60 lb.) also gave negative results except slight indigestion. The short period feeding experiments, were, therefore, found to afford no clue, whatsoever. He next fed a bull-calf of 8 months of age at the rate of 10 lb. of bracken with other food. The bracken was accepted quite readily. After a total consumption of 260 lb. over a period of 26 days the symptoms began to appear and the animal died on the 30th day with typical symptoms and post mortem findings as found in field-cases. Since the symptoms and lesions observed in the present disease were exactly similar to those described in "acute scurvy" in other species of animals, Stockman investigated the possibility of avitaminosis in the presence of bracken, in 1922. (27). In one experiment with a bull-calf, 4 months old, he used a mixed diet to exclude the possibilities of comparative starvation (green bracken + oats + bran). The idea was to include, in a curative role, a generous supply of swedes, which are known to contain a high quantity of anti-scorbutic vitamins, as soon as the animal showed symptoms. In spite of looking a little brighter after eating the swedes for a day or two, the animal died on the 30th day producing the exact post mortem lesions typical of bracken poisoning. The 2nd experiment:

experiment, on a calf 3½ months old with a generous supply of swedes from the very beginning of the experiment produced the same results, when, after eating a total quantity of 112 lb. of green bracken at the rate of 4 lb. for 28 days together with swedes, the animal died after 30 days.

Some veterinary inspectors, as quoted by Stockman, suspected bracken poisoning in several cases of pigs which died, as believed by the owners, from swine-fever. In the laboratory therefore, a pig was fed bracken at 2 lb. daily for 19 days but producing negative results. It may be possible, as believed by Stockman, that the period of feeding was too short to produce any reliable result.

The obscure nature of the disease was mentioned in text books even as early as 1912 (21). Later on, though Lander (21) gives a short review of experiments on the feeding of bracken to horses and cattle in his "Veterinary Toxicology" 3rd. edition, (1945) he leaves the conclusion open in view of some negative results recorded by Bruce. He, nevertheless asserts that bracken must be considered as a potential source of danger to cattle. No mention of the nature of toxic principle in bracken is made.

Bracken is an extremely common plant along the entire:

of North America
entire Pacific Coast especially in Oregon and Washington and from British Columbia to Alaska. Hadwen reported many ~~cases of~~ deaths of horses during January and February of 1916 on the banks of Fraser, and Vancouver Islands. This peculiar disease was also reported from many parts of British Columbia, specially on the Pacific Slope for many years and was generally known as "Staggers." As an extreme example, Hadwen mentions 16 deaths out of 24 cases; 4 recovered and the remaining 4 did not take the disease, in St. Elmo. Hadwen also states that they have evidence of such disease occuring in Washington and Oregon. Hadwen and Bruce (Preliminary Communication before the British Columbian Veterinary Association at Vancouver, B.C. December 16, 1916) pointed out that the condition could be reproduced by feeding bracken fern in both summer and winter, They published later (10) some preliminary experiments in which hay containing dried bracken was fed to an animal which died. The control animal had hay from which the ferns had been picked and did not take the disease. In this preliminary report the farmers were warned against the use of ferny hay, usually found in local markets. In this connection, a bulletin was published about this time by Hadwen and Bruce (11) in which they gave the reports:

reports of experiments in British Columbia on 5 horses. They stated that 6 lb. of dried bracken added to the daily diet kills a horse in a month's time. Pammel(22a) reviewed this in American Journal of Veterinary Medicine in 1917. The details of the experiment were published ~~later~~ in 1920 by Hadwen and Bruce (12). It must be remembered that the mortality was high during the hard winter of 1915-1916. Though the disease appeared mostly in severe and protracted hard winters, contrary to local belief, it is not necessarily associated with it. It may also be produced experimentally in summer. The only reason for its occurence in winter, might have been due to the fact that the animals get least exercise and are of lowered vitality during winter. Though the horses will not ordinarily accept ferns in hay, they are sometimes forced to eat ferny hay due to semi-starvation or occassionally greediness. The authors stated that the green bracken was never taken by horses or cattle, yet they referred (Oct. 1st. 1917) to 2 case reports where 2 horses fenced in an area browsed at the green bracken after finishing all the grasses in the area, by putting out their heads through the fence wire to reach bracken. One died and the other recovered. This therefore, according to the later:

later views of the authors did not exclude the possibility of healthy animals occa$sionally nibbling anything green within reach. Lawrance (15) has noticed the acquirment of a taste for bracken after the initial dislike has worn off.

Hadwen and Bruce (12) stated that the disease popularly known as "staggers" is due to ingestion of dried bracken over a certain period. They produced the disease experimentally in 4 horses. One showed symptoms on the 24th day and was destroyed on the 35th day when it was about to die. The 2nd horse did not show marked symptoms till the 38th day. They explained this difference in time as due to unavailability of bracken during the period of 12 days when green clover was fed by mistake. The 3rd animal was fed hay as purchased from the local market (containing 29% bracken) and death occured in 36 days. The average daily feed of animal No. 1 was 17 lb. of hay (contaminated with 20% bracken) and 7 lb. of bracken. In the 2nd experiment, the animal received on the average 13 lb. of hay (containing a high percentage of bracken, the percentage is not mentioned) and 11 lb. of bracken daily. In the 3rd experiment, one horse which served as control on clean hay only in the previous 2 experiments was switched on to experimental diet, e.g. ferny hay just as received:

received from the market and containing 29% bracken. The average daily feed was 20 1/4 lb. of which bracken composed about 5 3/4 lb. Careful weighing gave the total feed as 194.3 lb. of bracken (calculated together with 29% fern already present in hay). The 4th experiment was conducted on a strong healthy gelding to determine the quantity of bracken necessary to kill the animal with the reproduction of symptoms of the disease. The animal was fed 4.4 lb. of fern along with hay per day for 3 weeks* with no ill-effect. Next, when the amount was increased to 6.9 lb. per day definite symptoms of the disease were noted on the 29th day after this increase, and the animal was killed on the 35th day. From this experiment it was concluded that on average about 6 lb. of bracken had to be included in the daily diet to kill a horse in one month.

* and then reduced to 2.4lb per day with corresponding increase in hay for a period of further three weeks,

A criticism of experiment 4 may however be advanced on the ground that, assuming the toxin to be of cumulative nature, the effects were additive during the various changes of diet.

That an extract of bracken had no ill effect when administered to a horse, in concentrated form for a number of days was shown by the workers.

In this connection, it was noticed that if plenty of roots and hay are included in the diet with occasional bran and oats, no such trouble arose. It was therefore assumed:

assumed that small amounts of bracken can be eaten with a certain amount of freedom while only considerable quantities of bracken or ferny hay with unhygenic surroundings and lack of variety in the diet bring about the disease. Though there does not appear to be any reference to such a disease in horses in Great Britain, the authors state that some cases in the South of England have been noted. The animals were fed on ferny hay from Northumberland. This however is a report, not published, but communicated personally from the experience of an army veterinarian, L. D. Swenerton, after he went back to U.S.A. from this country.

Bosshart and Hagan (2) observed a"fatal undiagnosed disease" during 3 successive years. In 1917 they recorded 11 cases of which 10 died and 1 recovered; in 1918 the figure rose to 17 deaths and no recoveries and in 1919, the figure shot up still higher to 46 deaths and 27 recoveries. The peculiarity of the incidence was noted beginning from September and disappearing in November though cases in July were also known. The disease was found mostly on hilly and well-drained areas and though the pasture was quite good, and did not die back even after the first good frost. In 1919, in three instances cattle died in premises where the cattle:

cattle suffered in the previous year. This gave rise to a suspicion of infection but isolated cases were also known. In one instance, 9 cattle were removed 3 miles away from the site where 3 cases occured. Even then, 4 of these 9 animals were found attacked with this disease after 2 weeks. They mention that though the greatest susceptibility is observed in yearlings and 2 year-olds, the disease was found in all ages of cattle, some 20 - 50% of the herd being lost usually. On the other hand, occa$sional cases of 1 or 2 in a dairy of 12 are also noticed. On the basis of symptoms, course and disease the authors have differentiated acute and chronic cases.

Hagan, in the ~~2nd~~ Second part of the paper (2), states that he had been informed authoritatively by several veterinary practitioners that the disease ~~was~~ had been observed for many years past. He therefore attributed the cases seen in 1917, 1918 and 1919 to a severe outbreak of an old malady hitherto unidentified. He states that the disease affected a large number of cattle in 1919 and the mortality ran into hundreds. He referred to various places of occurence in New York State:-

Delaware County, Oneida County, Jefferson, several parts of Oswego and one place in Broome County.

In a later report, (22) Hagan definitely stated that:

that "the disease never occured at any time other than late summer and early fall and always ceased abruptly soon after the first killing frosts." In the fall of 1920 (13) the disease was again quite prevalent. In 1921-1922 only a few cases were noted but in 1923 the disease again became prevalent. In 1924, no cases were reported, but some might have escaped unnoticed. During late summer of 1923, in Chautanque County in the vicinity of Clymer, a number of cattle died. Here, on investigation of pasture, many ferns - ordinary bracken (brake fern - Pteris Aquilina) were found closely grazed by cattle. This gave rise to the suspecion that bracken might have been responsible. Bracken from such pastures was, therefore, fed experimentally to 2 cows. Each animal consumed 20 lb. of partially dried bracken per day and at the end of 5 weeks, remained healthy. In the opinion of the workers, though the animals do not usually take bracken, they do develop a taste for it during dry seasons when pasture is poor but it requires to be consumed over a long period to produce any symptoms.

The question of bracken poisoning was reviewed by Craig and Kehoe in 1925 (6) when they affirmed that the conclusions drawn by Stockman were correct, viz - that the disease could be reproduced experimentally by feeding:

feeding considerable quantities of bracken fronds over a long period, and that bracken is poisonous by ingestion.

Kerdiles stated that quite an alarming loss in cattle occur in Britany due to bracken-poisoning (14)

It is again highly interesting to note that a rather contradictory view is expressed in the Reports of the Veterinary Division in the Tasmania Journal of Agriculture (30). The common bracken (Pteris Aquilina) has been admitted to be poisonous to both cattle and horses and the possible poisonous effects have been ascribed only to the young fronds. Yet, they reported that the working bullocks commonly eat a large amount of bracken without any harmful effects.

In 7 cross-bred Herefords, 4 - 8 months old (3 heifers, 4 bullocks) Lynch noticed the disease (16). On enquiry it was discovered that bracken was used as litter often in fresh condition and the animals ate ~~them~~ it. Of the whole lot of 8 animals, 6 died. It is however doubtful if the animals got access to sufficient quantity of bracken to produce the disease, since it has very often been stressed in course of this review, by various workers that a sufficiently high quantity of bracken has to be consumed over a sufficiently long period to produce the disease. The only way the animals got access to bracken was from the litter from which, presumably, the whole could not be eaten without attracting:

attracting notice.

It has been noted that silages prepared from the fern (Pteris Aquilina) and kept for 9 months in ordinary pits have no detrimental effects. On the contrary this proved quite a satisfactory fodder which the cattle consumed readily (20).

About 1936, the existing literature was reviewed by Braid (3) stressing particularly the different sets of symptoms for different species of animals, cattle and horse, of this disease which will be discussed later.

There appear frequent correspondence in Scottish farming papers referring to such disease. The apparent poisoning by fern in "Auckland" was recorded in New Zealand. (The New Zealand Agricultural Journal, Vol. 1. page 215). Though no symptoms were noticed, 12 ewes and 18 lambs out of 70 ewes and 300 lambs died without struggle. That it was due to ingestion of bracken was concluded from the post-mortem findings of fern-shoots in a semi-digested state in the rumen. There were sorrel and fern in the grazing area. So, even if sorrel may be a possible cause of trouble, the post-mortem finding of:

of bracken is pretty suggestive of the cause. It may be mentioned here, that this seems to be the first report of such a disease occuring in sheep. In this country, sheep have never been reported to be poisoned by bracken though it will be referred to later, as a possibility as found by Fletcher.

In France, Lominet and Lavielle (17) described the clinical symptoms of ~~such~~ bracken poisoning in a small herd of cattle. The herd was fed indoors on a diet consisting of 25% meadow hay and 75% bracken fronds. They have suggested it to be a case of poisoning in the herd on bracken but nothing has been put forward to prove either the chemical nature of the toxin, or the age of such bracken fronds when it is supposed to be toxic. They even quoted Prof. Henry of Alfort having described bracken as a poisonous plant. Such conclusion, however, has not been supported by sufficient evidence.

Though it is generally believed that the young bracken fronds may be responsible for the poisoning in cattle, ~~(7)~~ Craig and Davies (7) have recorded cases of poisoning in October and this led them to assert that the old and not the young bracken is responsible for such poisoning. Mature bracken without any dilution with silage is therefore, thought to be dangerous to cattle health. This seems to be contradictory to findings:

findings recorded in Tas. J. ~~or~~ Agric. that young fronds only were responsible.

Maksimoff (20) found no harmful substance in silage prepared from bracken. This has already been mentioned. He did not, however, state the age of bracken fronds used for soiling. However, his findings gain support from the data published by Watson (32) who recorded absence of evidence of any injurious substance in silage prepared from young bracken fronds.

In a clinical communication ~~in Veterinary Record~~, Fletcher (9) distinguished 2 types of poisoning - (1) the enteritic and (2) acute laryhgeal. (9). He described symptoms, lesions, the diagnosis, the prognoses, and the post-mortem examinations results usually met with in practice. He considered the old and withered bracken to be more toxic and explained the early summer poisoning on two grounds:- 1) young shoots hit by night frost in summer and frosted and withered ~~and~~ are definitely more toxic in such a state. The natural distribution is in valleys, hollows and hill sides, where the fronds are shaded from the sum and are more toxic. 2) Cut bracken lying on the ground becomes toxic. He claims to have even recorded a case of a black-faced ewe with typical symptoms of bracken poisoning in June 1944. He also claims that the mysterious:

mysterious disease in sheep so often referred to during this period, bears some relation to such causes and needed investigation.

Shearer in 1945 (28) tried to produce the illness by experimental feeding of bracken. He put 2 heifers, 18 months old under experiment and fed the animal No. 1 on 20 lb. of chaffed bracken daily and No. 2 on 7 lb. of bracken and 7 lb. of a mixture of concentrates. The animal No. 1 became constipated and dull after 8 days and the symptoms appeared for the first time on the 13th day. He recorded various symptoms, temperature etc. regularly. This animal died after 74 days of feeding. Blood was collected twice a week regularly and revealed nothing of significance in the following:- red-cell count, percent haemoglobin, sugar alkali-reserve, non-protein-nitrogen, calcium, inorganic phosphorus and magnesium. The animal No. 2 did not show any symptoms, remained healthy and lived till the experiment was discontinued on the 78th day. Postmortem and bacteriological examination were carried out on No. 1.

Shearer is of the opinion that the experimental production of bracken poisoning was possible, though on a longer period than that observed by Stockman who has used younger animals and, in all probability, fern of higher toxicity.

He concluded that 1) bracken poisoning occurs only when:

when consumed in large quantities for a considerable long period. 2) Irritation of gut causes increased permeability of gut wall (this explains length of time required to produce symptoms) through which toxins are more readily absorbed. 3) He differs from the general opinion that the poison is cumulative in nature on the following grounds - a) the characteristic lesions are of an acute nature and not chronic as would have been expected in cumulative poisoning. b) it is only thought to be cumulative because time is needed to consume large amounts of bracken. The poisoning occurs, naturally, when the herbage is scanty owing to prolonged drought. The lower plane of nutrition due to low nutritive value of bracken would lower the resistance after which a decomposition product of catechol tannin, which he estimated in bracken, brings about the poisoning in cattle. Shearer's chemical analysis of bracken shows that if tannin is to be responsible, it is more likely to occur when the plants are nearing maturity. (6% in August and Sept. and brown and dying with only 0.44% in October).

Boddie (4) in a recent review of the subject brings out the following points:- 1) There is a considerable difference of opinion whether bracken itself causes the disease or whether it acts only as an exciting agent paving the path for bacterial invasion. 2) the diverg: ency of:

of opinion has gone to such an extent that one part of the country accepts the explanation of death in cattle on the grounds of toxicity of bracken, while the other part of the country strongly objects to such a view. 3) it is suggested that the variations in the weather may have an influence on the quantity of bracken eaten or the amount of toxicity in bracken.

Boddie also suggested that by removing the cattle from hill to low ground free from bracken at 3 weekly intervals - the losses can be avoided. The heavy mortality of cattle as seen in many parts of Scotland in 1946, in his opinion, might be due to the requirements of the Hill Cattle Subsidy Scheme (1946) which stated that the cattle must be on the hill continuously for 16 weeks. This alternative grazing has also been noted to prevent the disease to a certain extent. (33)

Recently much attention has been directed towards the possibility of the anti-thiamine activity of bracken which, when fed to rats at 40% level, caused death in a month with symptoms of thiamine deficiency. (34)

The literature has been reviewed from time to time. In 1925, Craig and Kehoe (6), in 1936 Braid (3), in 1941 Tocher (31) and in 1947 Stamp (29), and Boddie (4) reviewed the literature but the problem of bracken has remained as obscure:

obscure as in 1893, if not more complicated by divergent views.

C H A P T E R I

B. Symptoms.

Though this disease has been widely noted for so many years, the symptoms have been variously described from time to time.

Penberthy (23) described the symptoms and post-mortem lesions in cattle which were characterised by similarities in all the cases reported. The animals die within 1-5 days of showing the general symptoms which are:- extreme dullness, drooping of head and ears, back usually a little arched, skin dry and hard, discharge from eyes which become more and more sunken, foaming at mouth, blood and mucus discharging from nostrils, blood stained faeces, or blood clots (sometimes large) from anus, constipation often followed by diarrhoea, occasional tenesmus, swelling of throat and breast, breathing a little accelerated, pulse 70 to 80 small and feeble, temperature very high (as high as over 109°F has been noted) food sometimes refused and at other times freely partaken of and the rumination sometimes carried on with a temperature of 109°F. The depression and emaciation increased and the victims usually succumb with very little struggling though occa$sionally:

occas$ionally a little excitement has been noticed.

In 8 cases observed by Storrar (25) symptoms in cattle were almost like those found earlier by Penberthy and later by Stockman (26,27). In one particular case, however, there was no symptoms at all except bloody flux per rectum. ~~(8)~~

Freeman (8) described the symptoms, more or less in conformity with those already stated by Penberthy and Storrar, e.g. constipation, high temperature (103°-108°F) blood stained discharge from the nose, diarrhoea with advance of disease - foul smelling etc. One noteworthy symptoms, a deviation from earlier reports as already stated, is that prior to death the animal loses control of voluntary muscles and dies as if suffering from stomach staggers. In some of the cases again, he noticed no symptoms at all till the animals were found dead with blood passing out from anus, vulva and nostrils.

Later Nicholson Almond observed similar symptoms in cattle to those observed by previous workers, though no precise data or description are given of the experimental feeding and reproduction of the disease.(1)

The symptoms in cattle described from field cases in Stockman's report and ~~later~~ published in J. Comp: Path. in 1917 were as follows:- high temperature, up to:

to 107°F; loss of appetite, trickling of blood from the mucous membranes of the eyes, nostrils and vagina; passage of dark red and foul dung sometimes mixed with blood clots; swelling under skin; occa$sionally lameness; coma and death usually in from 12-72 hrs. after the first appearance of symptoms.

The general symptoms of the disease are more or less nervous in nature in horses - e.g. uncertain gait, loss of equilibrium, Then there are also - general unthriftiness, usually good appetite, prone to constipation; eyes congested; flanks tucked up; nervousness; the animal stands with legs spread with distinct intoxicated lØook and may fall. There was no abnormally high temperature in horses, such as has been recorded in almost all the cases observed in cattle by previous workers. It will further be noticed that no symptoms of bleeding from any part of the animal during the course of the disease was noticed, which on the other hand, is a constant characteristic of the disease in cattle (Penberthy, Storrar, Stockman, Freeman). These differences are hard to explain. The question is therefore still more confused by the production of different symptoms and lesions of apparently the same disease, in two different species of animals, horses and cattle.

Bosshart and Hagan (2) have distinguished two types of:

of this disease in cattle. The symptoms noted in acute type are as follows:- extreme high temperature 106° - 109°F (with haemorrhagic extravasatious) and death within 3 days; loss of appetite, minute petechiæ on the mucosa of vagina, nose and lips, (Specially lower lip and gums below the incisors), muzzle moist at early stage and dry later, haemorrhages from skin of scrotum of males in some cases, bleeding from skin looking like results of insect bites, dyspnoea in some and salivation in others, which in certain cases again drooled from mouth resembling foot and mouth disease, haematuria in certain cases, inco-ordinate movement of hind quarters in a few cases.

The "chronic type" lasted for 4 to 10 days or longer. Death almost invariably followed. Considerable emaciation, loss of appetite to a greater extent, bloody discharge from nose which, though scanty, continued for several days, muzzle dry, margins of nostrils coated with dried discharges with frequent foul odours arising from necrotic patches in the nostrils, pharynx, base of tongue or tracheae, were noticed. Necrotic areas were seen in many places like hips, shoulders, prepuce in bulls, region of fetlock and on the muzzle resembling lesions:

lesions produced by B. necrophorus Iéterus of all visible mucus membranes appeared in the disease and increased with prolongation of the disease. A very characteristic symptom was bloody diarrhoea, the blood in some cases was blackened but not abundant and sometimes large bright red clots were passed. The mortality was high, the animals die without struggle in from 4 - 10 days. The incidence of a chronic form was rare, less than quarter of the cases noted fell into such a class.

The only symptoms seen in 7 cross-bred Herefords 4 - 8 months old (3 heifers and 4 bullocks) were snoring, stertorous but not laboured breathing, slight salivation, animals off their feed, slight oedema in the throat region which on slight pressure intensified the respiratory sound. Lynch (16) noticed high temperatures of 106.4°F and 107°F but in the oldest of the animals (8 months) there was no abnormality in temperature (102°F). The deaths were quick and all the animals died within the course of a week. It is ~~highly amazing~~ remarkable to note the absence of lesions or symptoms ~~popularly~~ widely associated with "bracken poisoning" as noted by previous workers from the cases studied by Lynch. Excepting a slight rise of temperature (that too,:

too, absent in the old animal) there is no other similarity with cases previously recorded by Penberthy, Stockman, Storrar, Bosshart, Hagan and others. This dissimilarity in symptoms between other workers and Lynch, apparently over the same disease require corroboration (which is absent in the literature).

Libminet and Lavielle (17) have noticed one general symptom in particular e.g. diarrhoea from which all the animals have suffered.

Fletcher (9) described symptoms in 2 types (1) "enteritic type" - characterised by - symptoms of depression, high temperature (103° - 107°), weak pulse, enteritiøs with clots of blood in the faeces and pallid conjunctivae. This type is the more common. (2) laryngitic type:- shows - swelling in the throat region, roaring and difficulty in breathing, increased respiration and a high temperature.

Shearer (28) noticed in one experimental animal the main general symptoms as observed by Penberthy Storrar and Stockman, namely:- constipation, bleeding from the nose, high temperature, bleeding from anus, bloody discharge in faeces, diarrhoea etc.

It:

It will, perhaps be evident from the foregoing review of the existing literature that not much progress has been made in the study of the problem of bracken in relation to animal health; and certain contradictory findings have either to be confirmed or rejected or modified in view of the present-day knowledge.

Nevertheless, there are certain points which have not yet been clearly understood. Some of these are the following and need elaborate study:-

1) It has been noted that there is a great divergence of opinion relating to - possible toxicity of the plant, or in other words, whether the disease is experimentally reproducible. The age of plant responsible for poisoning, time of incidence of "poisoning" or "sickness" whether it is "poisoning" or "sickness" or "disease" or"Malnutrition".

2) There are no data regarding the nature of the toxin if present.

3) The post mortem pictures and symptoms of the disease are not yet well-defined or understood.

4) The ordinary chemical composition of bracken is very little known. ~~There are practically no data regarding this~~.

5) Moreover, no systematic feeding or digestibility trials:

trials have ever been carried out to study the nutritional aspect of the disease.

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CHAPTER - II

C H A P T E R II

Field Studies: Experimental Bracken Feeding (Pilot - Experiment) 1947-48.

Introduction

During the past few years, it was a subject of highly controversial nature, whether or not bracken was to be regarded as a potential source of danger to cattle. It will be evident from the foregoing review that failure to produce the illness on experimental bracken feeding was not unknown. The summary of the feeding experiments by various workers as noted below (Table I) therefore warranted a controlled feeding trial to determine:-

1. Whether ~~or not~~, the results would confirm the findings of the previous workers as to the toxicity of the plant, or in other words, whether the condition of illness could be reproduced experimentally.
2. the quantity of fresh bracken necessary to produce the illness.
3. the minimum period of feeding necessary to produce symptoms at a heavy rate of feeding (40 lb. of freshly cut green bracken per bullock daily, together with supplements:

TABLE I

"Summary of Feeding Experiments with bracken by various workers."

Investigator	Experimental Animal	Age	Amount of Bracken fed (lb)	Length of Experiment in days	Amount fed per day (lb)	Results	Remarks.
Stockman (1917)	Bull calf	8 mths	260	26	10	Died	Mixed diet. Gr. bracken + oats + bran
(1922)	Calf	4 "	160	30	5.3	Died	+ swedes.
(1922)	Calf	3½ "	112	30	3.7	Died	
(1917)	Heifer		56	9	6.2	Lived	Short-period experiments afforded no clue.
(1917)	Heifer		60	7	30 lb. for 1st 2 dys. followed by 6 lb a day for 5 dys.	Lived	
Hadwen and Bruce (1920)	① Horse		① 7 lbs + ferny hay	35	—	① Destroyed	① Showed symptoms on 24th day on Hay + Bracken
(1920)	② Horse		② 11 lbs + ferny hay	38	—	② ——	② Showed symptoms on 38th day
(1920)	③ Horse		③ 194.3	36	5.75	③ Died	③④ Symptoms on 35th day
(1920)	④ Gelding		④ —	35	6.00 (av)	④ Destroyed	⑤ Toxic principle not-soluble in water.
	⑤ Horse		⑤ Conc. Aq. Extract = 290 lbs	64	—	⑤ Lived	
Bruce (1927)	Heifer	3 yrs	578	262	2.2	Lived	May have been less toxic bracken
	Calf	3½ mths	264	30	8.8	Lived	
	Heifer	15½ "	495	40	12.4	Lived	
Hagan (1927)	Cow	6 yrs		52		Lived	Showed younger animals more susceptible than older ones.
(1927)	Bull	1½ "		52		Lived	
(1927)	Bull Calf	8 mths		66		Died	
Shearer (1945)	Heifer	18 mths	915	74	12.4	Died	Lower plane of nutrition - suspected high concentration of Catechol tannin.
(1945)	Heifer	18 "	678	78	8.7	Lived	

4. the age of the plant, i.e. whether young or mature or both contribute to illness. This will also indicate the highest concentration of toxic principle, if any, at a particular stage of growth of the plant.

In order, therefore, to investigate the various possibilities and to answer the various queries as laid down above, a scheme of experimental feeding and a plan of research were followed in the nature of a pilot experiment.

1. Sites of Feeding Experiment

On account of a heavy rate of mortality reported in 1946, from suspected cases of "bracken poisoning" in "Buckholm farm" near Galashiels, about 32 miles from Edinburgh and occupied by Mr. T. Barr, the following sites of experiment were selected:-

a) On a hill (Hogg Hill, elevation - roughly between 1000 - 1500 ft. above sea-level) where experimental animals were kept in special stone-built pens for intensive feeding on bracken. (Plate 1 Appendix).

b) another site was at "Williamlaw" where 2 stirks were kept in about 2 acres of fenced area for free grazing on bracken from 16th May, 1947.

2. Sampling of Bracken

The sampling of bracken began for the first time on:

on 12th June, 1947 when most of the very young fronds were just coming up, and was continued weekly till 6th of October 1947 when they were fully mature, brown and dying out.

In the beginning (12.6.47) 3 types of samples were available at one time:- (A) very young plants, all leaves totally closed or coiled up, green and brownish-green in colour, roughly 1" to 6" in average height and liable to be eaten up during grazings on grass, per chance.

(B) Medium Plants:- two side leaves with pinnules completely opened up, the third and central one still closed, roughly 6" - 10" in average height, green in colour.

(C) Fully Mature Plants:- mature, but not woody with all the leaves or pinnules totally opened, green and dark-green in colour, roughly 10" to 30" in average height.

About the middle of August, only the type C was available. Later on, from the last week in September, 1947, a different category of sample was the only one available:- (D) the mature and dried bracken, brown in colour, woody in conformation roughly 20" to 36" in average height. Similar plants of stunted growth were:

were also noticed.

The samples were air-dried, powdered and preserved for future analyses, to be reported in Chapter IV

3 Details of Experiment

a) Mode of Feeding

Two young bullocks (of cross Irish breed) of 2 - 2½ years of age were selected from the animals grazing freely on the same hill (site 1.(a)) and put in the pen for the first time on 3rd July, 1947. The next groups followed on different dates but at an approximate intervals of a month. The bracken was cut every morning and they were given freshly-cut bracken (including stems) of "B" and mostly "C" types, at the rate of 40 lb fresh weight per animal per day. The residue left was negligible. Water was allowed ad. lib.

After the death of the first animal (animal No. 2) on 7.8.47, the feed was supplemented by hay at the rate of 10 lb per animal per day and later, also by a cake mixture at the rate of 4 lb per animal per day to exclude the possibilities of any inadequate nutrition. The ration of cut bracken was allowed only after the animals finished the supplements. All the animals in the pen and the two on the site at Williamlaw (Site 1(b)) were:

were allowed this supplement beginning from 15th of August, till the 6th of October, 1947, - the end of the experimental feeding period.

The animals were kept under close observation during the experiment to study the development of symptoms.

b. Appetite

The animals were noticed to require only a couple of days to adapt themselves to the new ration. It must, however, be mentioned that the appetite was fairly good till about 3 or 4 days before the symptoms developed, when it gradually went down to a complete refusal of feed a few hours before death. In July and August, the green bracken was so much relished by the experimental animals that even the stalks (stems) were eaten to a finish. In the months of September and October, the appetite for bracken was found to be much lower, apparently due to the plants being dried and woody.

c. Total Food Consumption

Table No11 presents an approximate estimation of the consumption of fresh bracken, hay and concentrates over the experimental period.

d. Blood Analyses:-

were:

Table No.II

Total Consumption of Bracken and Supplements by Experimental Animals.

No. of animal	Age - years	Sex	Date penned.	Rate of bracken fed per day. (lb. fresh)	Total quantity of bracken fed (lb)	Rate of cake fed per day (lb)	Total quantity of cake fed (lb)	Rate of hay fed per day (lb)	Total quantity of hay fed (lb)	Length of experiment in days.	Remarks on Experiment	Nature of plant sample consumed.
1	2 - 2 1/12	♂	3.7.47	40	2720	4	96	10	240	68	Died on 8.9.47	B. C.
2	2 - 2 1/12	♂	3.7.47	40	1400	-	-	-	-	35	Died on 6.8.47	B. C.
3	2 - 2 1/12	♂	3.8.47	40	1360	4	88	10	220	34	Killed on 6.9.47 (sick animal)	B. C.
4	2 - 2 1/12	♂	3.8.47	40	2720	4	224	10	560	68	Discontinued 10.10.47	C. D.
5	2 - 2 1/12	♂	15.9.47	40	1000	4	100	10	250	25	Discontinued 10.10.47	Very little C. mostly D.
6	2 - 2 1/12	♂	15.9.47	40	1000	4	100	10	250	25	Discontinued 10.10.47	Very little C. mostly D.

were carried out throughout the course of the experiment, to be reported in Chapter III.

4. Results of Experimental Bracken Feeding

Animal No. 2

On 3.8.47, exactly after 33 days of feeding the animal was seen to be definitely sick. On a later visit, on 6.8.47, it was showing definite symptoms of bracken-poisoning between 3 and 6 p.m.:- 1. Total refusal of food, 2. weakness, staggering gait with occassional falling down on the ground unable to stand up. 3. Emaciated condition, 4. rattling noise from the lungs. 5. bloody mucous discharge from the nostrils. 6. constant salivation. 7. constant dribbling of urine. 8. temperature - 106°F. 9. Painful look. No blood could be seen in the stool. The animal died at 10 p.m. (vide post-mortem report in Appendix).

Animal No. 3

Put in pen on 3.8.47 was found sick on 5.9.47 and according to plan of the experiment, was killed on 6.9.47 to facilitate immediate examination and to avoid post-mortem complications. The only symptom noticed was weakness. Interesting pathological changes, especially in the wall of the abomasum and intestines were noted.

Animal No. 1:

Animal No. 1

Continued apparently healthy from 3rd July till the 7th of September when the animal suddenly refused food, passed black tarry faeces frequently and was found dead on the morning of the 8th September, 1947. The post-mortem examination was carried out in the field. A highly characteristic pathological picture of certain organs was noticed. Extensive haemorrhages in subcutaneous tissues and blood extravassation of extensive nature, specially in abdomen and small intestines, were noticed. This case could possibly be classed as "chronic" type. (Plate VI and VII Appendix.)

Animals No. 4, 5 and 6.

Continued apparently healthy till 10.10.47. As the bracken was dying out, the experiment was discontinued. One of the animals, No. 4 was sacrificed but revealed nothing of pathological significance.

5. Histological Studies

The tissues from animals No. 2, 3 and 1 were preserved in formol-saline fixative. On examination, no significant results could be obtained excepting those usually associated with haemorrhagic symptoms.

6. Post-Mortem Examinations

The results are included in the appendix. (vide Appendix. Page 2)

Discussion of Results

1. As shown in the experiments described above, the illness commonly known as "Bracken Poisoning" could be induced experimentally in male bullocks of 2 to 2½ years of age on feeding fresh bracken at a heavy rate of 40 lb daily (fresh weight) for at least 30 days. The animal No. 2 died on the 35th day and the symptoms of illness shown could easily be differentiated from those of animal No. 1 which took nearly double the time (about 68 days). On the basis of symptoms, post-mortem picture and length of time needed, it has been possible to distinguish, a comparatively acute (case No. 1) and a chronic (case No. 2) case. As the experiment started this year (1947) in July, the nature of bracken grown in April, May or June could not be determined this year. At any rate, it has been possible to produce the illness in these 2 cases. The 3rd animal was also sick and would have possibly died in course of a day or two. This animal was killed for immediate post-mortem examination to exclude possibilities of post-mortem bacterial invasion and interference in diagnosis. This was particularly necessary because we could not perform the post-mortem examination of the animal No. 2 on the night of death. The:

The post-mortem results of this animal was, however, similar to those found in the case of the other two animals which died. This proved that the animal No. 3 did take the disease and excluded the general view (as mentioned by Shearer (6)) that all changes are mostly subsequent bacterial invasion.

Age.

Considering the summary of the previous feeding experiments (Table I), it appears that Stockman (2) was able to kill younger animals, (3½ to 8 months old calves) by feeding bracken quite readily, whereas Bruce (4) obtained negative results even with larger amounts of plants. The only reason which could be attributed to such negative results, seems to be the varying toxicity of the samples used in the two experiments. It also appears from the previous experiments that the younger animals were more susceptible than the older ones in view of the negative results obtained by Hagan and Zeissig, 1927 (5) in both the cases, cow 6 yrs. old and bull 1½ years old. Supporting this view, Anon (7) points out in a brief note, the danger of feeding cattle on bracken in Victoria and believes that calves are more prone to it than the adults. It might have seemed possible, therefore, that the age of animal is of some importance. Yet, in view of the positive results:

results obtained with bullocks 2 - 2½ yrs. of age, in the present experiment, we may mention that our results seem to support the view expressed by Storrar (8) that the illness occurs in all ages.

It will be observed that in order to ascertain the period of incidence of the disease, the animals were put in 3 separate batches, in different months into the pen. The interval was approximately about a month. Table 2 shows that the animal no 1 and no. 2 put in the pen on 3rd July died at different dates, No. 2 on 6.8.47 and No. 1 on 8.9.47. One of the animals, No. 3, put in on 3rd August was seen sick but the other one did not show any symptoms at all and was discontinued. Animal No.5 and 6 put in pen in September did not take the disease. It will not, therefore, be far from correct to state that the period of incidence may be marked down as from July to September. The animals No. 5 and 6 put in the pen on September 15th did not show any symptoms even when the experiment had to be discontinued because the bracken was withering away and was hard, woody and fibrous not normally liable to be taken by animals in open fields. We have, however, no record here previous to the month of July. (It is however, proposed to repeat the experiment earlier next year (1948) when the:

the bracken is just sufficiently grown to be grazed. The results of the present experiment, during this season, indicated July to September to be the most likely period of incidence. Stockman (9) reported almost all outbreaks to be strictly limited to the period of Autumn, i.e. August to the beginning of November; whereas Hadwen in America observed deaths in horses in January and February and assert that it can be reproduced in Summer and Winter both.(10) Shearer (6) in Great Britain, has recorded death in the month of September beginning his experiment in the middle of July. This however, fits in with his theory of tannic acid poisoning as evident from his analytical data which records highest concentration of catechol tannin in bracken during July (7.00%), August (6.04%) and September (6.26%) It may be mentioned here that our analyses of plants do not give such figures though frequent samples have been analysed by an improved Colorimetric method of Mitchell. Reference will be made to this theory in a subsequent chapter.

As mentioned in the preface, most of the workers have noted the illness during the autumn and summer months.

Age of the Plant:

Although:

Although the popularly termed "Bracken Poisoning" has been noticed from time to time, beginning from 1893, there is very little reference in the existing literature, about the correlation between the age or height or stage of growth of the plant and the onset of illness. It is however, generally believed that the young fronds may be responsible for the poisoning in cattle. In the reports of the veterinary division of the Tasmania Journal of Agriculture, (11) the possible poisonous effects of Pteris Aquilina, common bracken, has been ascribed to the young fronds only. This view is supported by several cases reported in early summer months. As opposed to such a view, Stockman in 1917 (1) held that the mature bracken fronds fed continuously without any other forages was dangerous to livestock. In support of this belief he recorded outbreaks of such illness on several occassions to be limited strictly to the Autumn period, August to the beginning of November. Further, Craig and Davies (12) have recorded cases of poisoning in October and assert that "the old and not the young bracken which is responsible for such poisoning". This view is somewhat supported by the absence of any evidence in the silage from young fronds that they contained any substance which would be injurious or dangerous to cattle:

cattle health.(13) This, however, should be regarded with a limitation, as the effect of soiling on the possible toxic agent is not known. Fletcher (14) states that the old and withered bracken is regarded as the most toxic. Summer poisoning was explained by him on 2 grounds, - 1. Young bracken shoots affected by night frost become extensively brown and the tender young shoots wither quickly which are more toxic. Hadwin and Bruce (3) do not distinguish bracken fronds by age as they recorded experimental poisoning in horses both in Summer and Winter. Shearer (6) does not mention the age of bracken fronds but his experimental results indicate that the animal No. 1 fell sick in the month of September (Table I vide(6)). It will be evident from Table II, that bracken in July was at maximum growth and commenced to wither in September. We may regard it to lend support to the view that mature plants are more likely to contribute to illness.

In the present experiment it will be seen from Table II that the animals No. 1, 2 and 3 were mostly on B and C type bracken. Type B according to our classification, is a medium plant of which 2 fronds have completely opened while the central one is still closed. 6" - 10" in average height, green in colour. Type:

Type C was fully mature, green or dark green in colour but not quite woody or brown 10" - 30" in average height. The animal No. 2 which died on 6.8.47 consumed major portion of "B" types and some "C" types available in August. This excludes the assumption that only the fully mature plant of C type was responsible, for illness. Animal No. 1 had mostly "C" type of bracken and took a considerable length of time (about 68 days) to develop symptoms. Animal No. 3 was sick with comparatively larger proportion of C bracken. Animals No. 5 and 6 were discontinued as D type of bracken could not possibly be fed without severly affecting the nutritional requirements of starch and protein equivalents. Moreover, the plant was quite woody and dry with a very high proportion of fibre. Even then, 25 days of feeding did not show any symptoms, neither any changes in the internal organs on autopsy on one animal No. 4. In view of these findings, it is not improper to suggest that green plants of medium and mature growth are liable to produce illness, as are also the young ones available in July. Information regarding still younger bracken of Type A could not be obtained this year. The next season may afford an opportunity to examine critically the nature of A-bracken in April, May and June. The assumption, therefore, that:

that brown and withered plants are more toxic, as visualised by Fletcher (14) needs further corroboration which could not possibly be carried out with bracken as the only source of food without any other succulent food, as it would imposes extreme conditions.

Quantity of Bracken

The quantity of bracken necessary to produce illness was found to be roughly 40 lb fresh weight per animal per day for at least 30 days. (minimum period). The weight of the sample cut every morning will of course vary a great deal with the moisture content, not only of the plant but also of the weather. At any rate, a heavy level of feeding bracken is necessary to produce illness.

Stockman fed a much smaller quantity (1, 2). It must however be remembered that the animals under his experiment were younger and smaller in live-weight. The period taken was almost the same-26 days. He, however, included other foods along with bracken to supply adequate energy. In the present experiment, it was the aim to feed at as high a rate as possible. Hagan does not give any record of the quantity of bracken fed. Hadwin and Bruce observed that the inclusion of 6 lb. dried bracken in the daily diet would kill a horse:

horse in a month's time (3) Shearer fed 915 lb in 2½ months at 12.4 lb. per day as the sole source of food to animal No. 1. As bracken is definitely a poor source of food, 12.4 lb. of fresh bracken might have been inadequate to meet the ordinary energy requirements of the animal and might have contributed to the starvation of the animal. The animal No. 2 in his experiment had an equal proportion of highly nutritious cake mixture along with 8.7 lb of cut bracken daily. This animal lived. The experiment with animal No. 1 may be criticised on the ground of inadequate nutrition, as the animal was under a condition of malnutrition from the beginning of the experiment. The animals in our experiment had only freshly cut bracken as the sole source of food. It was therefore, thought necessary to allow bracken at the heaviest possible rate. Even then, after the death of animal No. 2 in the first instance, it was thought desirable to include highly nutritious supplements, i.e. hay and cake, to exclude any possible criticisms of under nutrition.

From our experiment, one very important fact stands out, that to produce the illness experimentally, a very heavy rate of feeding bracken is essential, continuously:

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continuously over a considerable period of at least 30 days - thus lending support to the cumulative nature of the toxin, if any, in bracken. This observation, supports the majority of the workers like Stockman (1917,22), Hagan (1927), Hadwen and Bruce (1920), Shearer (1945).

Symptoms

The symptoms of this illness have been variously described by previous workers beginning from 1893. In the present experiment, the animal No. 2 showed the following symptoms:- 1. loss of appetite during last 2 days. 2. weakness, staggering gait with occasional falling down on the ground - unable to rise. 3. emaciated condition. 4. rattling noise from the lungs. 5. bloody mucous discharge from nostrils 6. constant salivation. 7. constant dribbling of urine. 8. temperature high - 106°F. 9. painful look.

1. The loss of appetite was marked only a day or two from the time of death. Describing the general symptoms of field cases, Penberthy (15) mentions that sometimes food was refused but at other times freely taken. This, therefore was not a constant symptom. Stockman (1, 2) noticed this loss of appetite in field cases:

cases. Experimenting with horses on the other hand Hadwèn and Bruce (3) were surprised to find good unimpaired appetite allthrough the experiment. Bosshart and Hagan (16) observed the loss of appetite in "acute" cases and to a still greater degree in chronic cases. The same symptom was noted by Lynch (17) in 7 crossbred Herefords 4-8 months old. Shearer (6) does not mention any such symptoms. In the present experiment, the loss of appetite was noted in the sick animals only a day or two before death or before being killed (No.3).

2. The weakness and staggering gait was noticed in animal No. 2 only. This resembled to a very slight extent the symptom observed by Hadwèn and Bruce in horses which they explained as nervous in nature giving rise to loss of equilibrium and uncertain gait. It should, however, be noted that this symptom was noted only in this isolated case No. 2 and not in others to be of sufficiently general in nature.

Emaciation was noticed by many workers. In the present experiment none of the animals presented an extremely emaciated condition.

Animal No. 2 showed symptoms of stertorious breathing giving rise to rattling sounds as observed by Lynch. Other animals did not present this particular symptom:

symptom.

Many observers like Penberthy, Storrar, Freeman, Stockman, Bosshart and Hagan, noticed the main symptom of bloody discharge from mucous parts, mainly nostrils, vagina, etc. Lynch however, did not notice such symptoms. Shearer observed such bleeding from the nose and anus. Fletcher does not mention bloody mucous discharge but refers to clots of blood in faeces, as mentioned by Penberthy, Storrar, Stockman, Bosshart and Hagan, and Shearer. It will be observed in the present experiment that animal No. 2 suffered from bloody mucous discharges from the nostrils but no blood could be traced in the stool. The animal No. 1 again passed clotted blood in the stool, but no bloody discharge from the nose could be detected. It is thought that in cases of chronic illness, as observed in No. 1, there is blood in the stool whereas in acute cases no such blood in the stool is present. The question is still further confused by the findings of Hadwen and Bruce that not the least signs of haemorrhagic discharges from nose or anus are noticable in these animals.

While most of the workers like Penberthy (109°F), Storrar, Stockman (107°F), Freeman (105° - 108°F), Bosshart and Hagan (106° - 109°F), Lynch (106.4° - 107°F) except in an old animal 102°F), Fletcher (103° - 107°F) and:

and Shearer (103° - 107.6°F) have observed high temperature in sick animals, in the present experiment animal No. 2 only showed a very high temperature of 106°F.

Post-Mortem Examinations.

Results are given in the appendix - Page 2, and plates are shown (No. VII and VIII).

Field Studies 1948

In order to study the effect of heavy stocking on bracken land, 10 cattle were enclosed on 30 acres of Hogg hill and 7 on 20 acres of Williamlaw hill. These enclosures contained a thick growth of bracken, together with grass and heather. Owing to the particularly wet season, there was a plentiful growth of grass. Nevertheless the animals were seen to graze the tops of the bracken quite freely.

One of the animals on Williamlaw was seen to be sick on 26th August, 1948 bleeding from nostrils and rectum. It died in the afternoon of the following day and the post-mortem picture was exactly similar to those previously noted in 1947.

Summary:

Summary

1. The 1947 field experiment showed that the disease can be produced experimentally by feeding green bracken at a heavy rate.

2. The disease may also occur under field grazing conditions where the stocking is heavy, as found in 1948.

3. Although the cause of the disease remains uncertain there is considerable evidence for the belief that bracken contains a factor which is either directly toxic or leads to the development of a severe nutritional disorders.

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C H A P T E R II

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C H A P T E R - III

C H A P T E R III.

Studies on the Composition of Blood of the Animals During Experimental Pro-:duction of The Disease.

Introduction

It has been generally known that most diseases alter the composition of the blood to a certain degree. It has also been known that the examination of blood would afford a diagnostic clue to many known diseases. The present investigation was undertaken because:-

a) the present disease or "Bracken Poisoning" does not fall under any of the known diseases of which a complete blood picture is now established.

b) The post-mortem and the pathological findings as described in Chapter II (vide Appendix) bring out one very outstanding feature, namely, excessive extravasation of blood in many tissues and organs. One of the symptoms noted in case No. 2 was "bleeding from the nose". All these indicate, possibility of some derangement, somewhere, either in the (i) mechanism of circulation e.g. clotting power of blood. or (ii) in the chemical composition of blood or (iii) due to the presence of some toxic substance in the general blood stream, e.g. which may be an excess of any of the narmal:

normal constituents in toxic concentration.

d) The characteristic lesions of the disease, e.g. "haemorrhage" bears close resemblance to that seen in "sweet clover disease". In recent years, this haemorrhagic symptoms in "Sweet clover Disease" has been proved due to loss of clotting power of blood. The causative agent has been shown to be "Dicumarol" (1). It was therefore necessary to determine the clotting power of blood in the present disease, to examine any correlation.

Experimental.

After the sudden death of Animal No. 2 showing characteristic haemorrhagic symptoms, blood samples were collected at frequent intervals from the experimental animals in the field, at Buckholm farm, Galashiels. These were brought back within 2 hours to Edinburgh in ice-filled thermos flasks, for analyses.

Sampling for analyses:-

Whole Blood:- The standard methods of sampling were employed, sodium citrate (5 mg per ml blood) being used as anticoagulant.

Plasma:- was obtained from freshly drawn blood which was allowed to clot at 37°C in an incubator, chilled thoroughly in refrigerator and then centrifuged to sample the supernatant serum.

The Blood Filtrates:- were prepared by precipitation of whole blood with trichloracetic acid or tungstic acid according to standard procedures described by Peters and Van Slyke (2).

The blood of animal No. 2 could be sampled for the first time, only a few minutes before death and in the absence of any anticoagulant being readily available in the field, the whole blood was collected to obtain serum for analysis.

The results are given in Tables No. III and IV.

Constituents Estimated, Methods used and Results

A. In the whole blood

a. Total Haemoglobin:- The values of from 6.35 gm to 11.8 gm per 100 ml blood were determined by the colorimetric acid-hematin method of Newcomer with glass standard. (3) No significant change with the progress of the experiment was noted although the heamoglobin content in animals 1, 3 and 4 were near the lower level of normality (20). Fletcher (4) recorded an anaemic blood picture (low Hb) in animals suffering from the disease.

b. Prothrombin time at 37°C:- This was estimated by Fullerton's modification of Quick's method (5) as follows:- 9 ml. of blood was added to 1 ml M/10 oxalate and:

oxalate and cetrifuged for 5 mins. 0.1 ml of plasma was drawn out carefully and mixed with 0.1 ml "stypven" (Russel viper venom), incubated for 1 minute at 37°C in waterbath. 0.1 ml of M/40 $CaCl_2$ was then added. Time was carefully noted for first sign of clotting indicated by granulation in the nature of spider-web like threads.

The estimations were carried out at the Department of Clinical Surgery, University of Edinburgh, by the courtesy of Dr. Burt under the direction of Professor Gaddum.

The results obtained as shown in table 1 appendix, are normal.

c) Total counts of R.B.C. and platelets:-

Standard methods (6) were employed for one set of estimations on 6.10.47. The results as noted below were within normal range. The estimations were, therefore, discontinued.

Animal No.	Total R.B.C. Count per C mm.	Total Platelets count per C mm
4	4,800,000	196,000
5	6.100,000	342,000
6	5,780,000	256,000

B. <u>In Blood Filtrate</u>:-

a) <u>Blood Sugar</u> was determined by Folin Wu method (7). The:

The values which lie between 51.8mg and 63.7 mg per 100 ml blood are within normal range. No decrease with progress of disease was noted.

b) Chlorides as NaCl were determined by the method of Whitehorn (8). The values from 490 mg to 540 mg per 100 ml blood are normal. There was no significant change.

c) Total Acid Soluble Phosphorus. The organic matter in an aliquot of trichloracetic acid filtrate was destroyed by digestion with sulphuric acid and subsequent oxidation with pure and concentrated Nitric acid. The remaining clear phosphate-containing solution was subjected to phosphate determination by the method of Fiske and Subba-Row (9). The values are within normal range of 10.81 to 16.9 mg.

d) Inorganic Phosphate was determined by the method of Fiske and Subba-Row. The values recorded were normal (9)

e) Non-protein Nitrogen was determined by the method of Folin and Wu (10). The values are normal.

f) Amino-acid Nitrogen was determined by the method originally proposed by Folin (11). The values (5.60 mg to 9.75 mg) are within normal range.

g):

g) Preformed Creatinine:- was determined colorimetrically by the method of Folin and Wu (12). The values noted (1.04 mg to 1.70 mg) are within normal range indicating no possible defect in endogenous protein metabolism.

C. In Plasma

a) Fibrin:- was precipitated by the method of Cullen and Van Slyke and was determined colorimetrically by the method of Wu and Ling using original Folin phenol reagent for developing colour. The values were normal. (13).

b) Albumin and Globulin:- were determined mainly by the improved method of Wu and Ling which was modified by Greenberg by using the new improved phenol reagent of Folin and Ciocalteu and by using Sodium sulphate proceedure of Howe for separating proteins.(14)

The values were found to be within normal range. It is seen therefore, that the blood protein fractions are not responsible for the haemorrhagic symptoms.

D. In Serum

a) Calcium:- was estimated by the Clark-Collip modification of the Kramer-Tisdall method (15). The values are normal.

b) Magnesium:

b) Magnesium:- was determined by the method of Denis modified to develope the colour of phosphate by the method of Fiske and SubbaRow (16). The values are within normal range.

c) Potassium:- was estimated by precipitation with cobaltinitrite as devised by Clausen and further developped by Kramer and Tisdall (17)

The values are within normal range.

d) Sodium:- After deproteinization, the sodium in the clear filtrate was precipitated in alcoholic medium as triple salt, uranyl-zinc-sodium acetate which was washed with alcohol and ether dried at 37°C for 4 hours and estimated gravimetrically. (18).

The values are within normal range.

Tables no. III and IV show the results of analyses, on different occassions (at different intervals).

Summary.

It will be observed that the data presented are within, or very near, the normal range.

It is concluded that the blood of animals sufferings from this disease does not show any significant change in the constituents examined. This is in agreement with the findings of Shearer. (19).

Fibrin:

Table III

Analysis of Blood of the Experimental Animals Fed on Bracken at 40 lb. daily.

Animal No.	Whole Blood: Dates of Bleeding	Whole Blood: HC (Gm 100 ml)	Blood-Filtrate (mg per 100 ml. blood): Sugar	NaCl	Total Phos.	Inorg.P.	N.P.N.	Amino. N.	Preformed Creatinine
1	11.8.47	7.90	52.7	490	10.81	5.95	16.67	-	-
	25.8.47	7.49	53.5	500	12.70	8.79	-	-	-
	1.9.47	6.71	51.8	520	16.50	7.84	24.49	6.67	1.04
3	11.8.47	6.70	63.70	510	-	6.45	22.86	-	-
	25.8.47	7.35	61.80	520	13.20	9.30	-	-	-
	1.9.47	6.35	55.56	540	15.90	6.78	-	5.83	1.45
	6.9.47	7.14	60.95	510	12.90	4.97	22.50	5.60	1.36
4	11.8.47	7.20	58.20	500	13.79	5.93	17.78	-	-
	25.8.47	7.68	57.80	530	11.70	6.96	-	-	-
	1.9.47	7.98	53.45	520	18.50	7.27	-	5.85	1.40
	8.9.47	7.25	57.20	520	13.70	8.25	36.20	9.33	-
	15.9.47	7.14	62.10	530	16.90	7.27	29.60	6.48	1.50
	22.9.47	8.75	58.80	520	12.70	8.42	32.30	7.22	1.70
	29.9.47	8.94	53.45	510	12.30	7.84	32.40	6.61	1.60
	6.10.47	7.88	60.60	530	-	8.42	33.30	6.90	1.70
5	15.9.47	9.4	65.40	500	14.50	8.33	33.00	6.76	1.60
	22.9.47	11.1	65.80	510	14.90	8.89	35.50	8.25	1.70
	29.9.47	9.7	57.15	510	12.80	7.92	41.40	7.69	1.50
	6.10.47	9.9	57.45	520	15.10	8.70	34.30	6.45	1.60
6	22.9.47	11.8	63.30	510	14.00	7.48	42.00	9.75	1.70
	29.9.47	10.3	55.75	520	12.00	6.90	41.40	8.75	1.50
	6.10.47	9.6	63.30	530	14.50	8.99	44.40	7.87	1.40

Table No. IV

Analysis of Blood of the Experimental Animals Fed on Bracken at 40 lb Daily.

Animal No.	Dates of Bleeding	Blood Serum (mg per 100ml blood) Ca	Mg	K	Na	Blood Plasma (mg per 100 ml blood) Fibrin	Albumin	Globulin	Remarks.
1	11.8.47	9.90	2.33	25.00	334.20	-	-	-	Died on 8.9.47
	25.8.47	9.08	2.19	24.42	328.60	0.43	-	-	
	1.9.47	9.50	2.09	23.43	330.10	0.41	-	-	
2	6.8.47	12.00	2.39	24.42	326.01	-	-	-	Died on 6.9.47
3	11.8.47	10.10	2.24	23.29	336.90	-	-	-	
	25.8.47	8.00	2.06	25.42	332.10	-	-	-	
	1.9.47	9.50	2.11	22.01	337.80	0.33	2.06	4.16	
	6.9.47	9.20	2.44	23.15	324.10	0.53	1.62	4.64	Killed on 6.9.47
4	11.8.47	8.70	2.28	22.44	331.90	-	-	-	
	25.8.47	9.06	2.12	23.43	326.80	0.32	2.06	5.20	
	1.9.47	9.30	2.07	22.72	334.90	0.41	-	-	
	8.9.47	10.50	3.05	-	320.70	-	-	-	
	15.9.47	9.60	1.66	22.12	349.80	0.41	-	-	
	22.9.47	9.07	2.35	23.29	321.50	0.42	2.04	5.41	
	29.9.47	9.87	2.97	24.85	317.30	0.38	2.10	5.21	Discontinued on
	6.10.47	9.60	2.20	23.43	328.30	0.37	2.45	3.29	10.10.47
5	15.9.47	10.00	1.57	20.30	360.30	0.47	2.06	4.43	
	22.9.47	9.07	2.43	22.72	326.30	0.43	2.12	4.85	
	29.9.47	9.87	2.23	29.82	291.60	0.40	2.14	4.92	Discontinued on
	6.10.47	9.80	2.23	22.01	315.30	0.40	2.22	3.50	10.10.47
6	22.9.47	10.15	2.48	25.70	330.00	0.48	2.29	4.85	
	29.9.47	-	2.65	26.84	316.10	0.39	2.39	4.39	Discontinued on
	6.10.47	9.90	2.34	19.45	325.30	0.40	2.32	4.18	10.10.47

Fibrin was estimated to trace any defects in the mechanism of clotting power but afforded no clue whatsoever.

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C H A P T E R - IV

C H A P T E R IV

A. "The Chemical Composition of Bracken at Different Stages of Growth Throughout the Season."

Introduction

Since the examination of blood of the diseased experimental animals did not reveal any significant clue, attention was naturally diverted towards any possible indication in the composition of the feeding stuff, viz. freshly cut bracken from Buckholm farm, Galashiels.

In order to ascertain the possible economic value of bracken as cattle feed during wartime, Ferguson and Armitage (1) studied the composition of bracken from June to November at 15-day intervals. Several changes in the concentrations of the various nutrients were noted in relation to the progressive growth of the fern, e.g. fall of crude and true proteins, potash content and sugar concentration; the lignin and cellulose contents were high throughout and increased further towards the end. The laboratory digestibility of protein by the pepsin - HCl method or artificial trypsin digestion yielded unsatisfactory and negative results. It will be noted that as the study was merely from the economic point of view, no attempt was:

was made to correlate any of the constituents with "Bracken Poisoning".

It is also clear from the literature (vide Ch. I) that there is much difference of opinion as to the stage of growth when the plants are toxic.

Smith and Fenton (2) studied the composition of bracken fronds and rhizomes at different stages of growth, determining the percentages of protein, K_2O (total and water soluble), SiO_2 and carotene. They found the nitrogen and carotene contents of bracken to be similar to those of other green forages.

Shearer (3), in 1945, experimentally produced "Bracken Poisoning" in a heifer and also studied the composition of the bracken fed and the variations during growth, to determine, if any constituent could possibly be responsible for the illness. No definite conclusions were reached though a high tannin concantration at a particular season was suggested as a possible cause of toxicity when the animal was undernourished as a result of the low nutritive value of the bracken.

In view of the very insufficient data regarding the composition of bracken (particularly of bracken found in Scotland) it was thought desirable to carry out a systematic estimation of the various constituents in bracken:

bracken, particularly that fed to the experimental animals, as described in Chapter II. The main purposes of these analyses were (1) to assess the nutritive value of bracken (2) to attempt to relate the toxicity to a particular constituent and (3) to examine the theory of tannin toxicity advanced by Shearer. The study of chemical composition was all the more necessary, as Shearer mentions "a search of the literature showed that no systematic chemical examination of bracken had ever been undertaken".

Details of Experiment

Samples were collected from Hogg Hill, Buckholm farm, Galashiels, where many cattle died in 1946 and where experimental animals were kept in 1947. The sampling of bracken began on 12th June, 1947 when most of the young fronds were just coming up and was continued weekly until the 6th of October 1947 when they were fully mature, brown and dying out. Aliquots of the fresh bracken fed to the experimental animals as described in Chapter II were also collected. The leaves and stems were dried separately at room temperature, powdered and preserved for analyses.

Methods of Chemical Estimations

The:

The percentages of the following constituents were estimated in leaves and stems separately:- moisture, total ash, crude protein, ether extract, silica (SiO_2), phosphate (P_2O_5), Calcium (CaO), Crude fibre. The methods used are standard methods too well-known to be described here (4, 5).

Crude protein was calculated from the percentage of nitrogen (determined by the Kjeldahl method) multiplied by the conventional figure of 6.25. The percentages of N.F.E have been obtained by difference in the usual way.

Total K_2O was determined by the method as described by Piper (6), and the soluble portion in 5 gms. was extracted by boiling 5 times with 100 c.c. portions of distilled water. The percentage of K_2O in the residue was determined and the percentage of soluble K_2O calculated by difference.

Tannin was estimated by an improved method of Mitchell (7) as follows:- 1 gm. of air dried and powdered bracken was extracted by boiling with 100 c.c. tap water for ½ hour and filtered. The residue was similarly re-extracted with about 100 c.c water each time boiling for 15 mins and filtering through cloth (parachute silk). In all, 5 extractions were made, although removal of tannin was found to be complete, after:

after the 4th extraction, as the filtrate gave no colouration with $FeCl_3$ solution. The combined extracts were made up to 500 c.c. and filtered through filter paper. To an aliquot of this 500 c.c., 0.1 c.c. of N/10 Na_2CO_3 was added and the volume made up to 100 c.c. with tap water in a Nessler's tube. One c.c. of 0.1 percent solution of pure Osmic Acid (Osmium tetroxide) was then added. The colour developed after 15 mins. was compared against a standard of 1 c.c. of 0.1 percent pyrogallol similarly treated. By altering the volume of bracken extract, the colour can be matched and the concentration of catechol tannin measured.

Pepsin-HCl digestion

The method followed was that recommended by A.E.A - Analysis of Fodders Subcommittee (8).

Two samples of bracken leaves at approximately the period of feeding (vide Chapter II) were examined along with a sample of dried grass for comparative purposes. Digestibility of nitrogen was estimated in various ways:-

i. Samples of (a) bracken, (b) grass and (c) mixtures of bracken and grass were examined to see if there was any interaction due to the tannin content of the bracken.

ii. Similar samples were washed by boiling with 5 separate portions of water to get rid of tannin and the digestibility:

digestibility of the nitrogen in the residue determined.

iii. Samples of dried grass and bracken were separately washed before being mixed and subjected to pepsin digestion.

Results and Discussion

Tables V, and VI give the percent composition on a dry matter basis.

Total ash and silica-free ash:- The "Total ash" or mineral matter is within a range of 5.2 and 8.3 (leaves) and 5.2 and 7.1 (stems) percent and does not show any variation with growth. The silica however increased in percentage from 0.5 to as much as 2.9 as the leaves matured and from 0.4 to 1.8 in the stems, in consequence the true mineral matter or "silica-free ash" decreased with growth.

The percentage of ash in the dry matter of 6 samples reported by Hendrick (9) ranged from 6.96 to 14.82 percent (av.9.11) whilst Maxwell (10) found 4.82 percent in an air-dried sample. Russel's (11) figures for 2 samples were 3.61 and 5.87 per cent. Shearer (3) recorded 8.14 percent total ash and 7.61 percent soluble ash in May, and between 5 and 6 percent total ash and 3.55 to 5.7 % soluble ash between June and October. The figures for total and soluble ash obtained in this investigation were thus quite similar to those previously reported by Shearer:

Shearer (3).

CaO

Calcium gradually increased with age from 0.4 percent to as much as 1.08 percent in the leaves whereas it was practically constant (0.2 to 0.4 percent) in the stems.

Ferguson and Armitage (1) obtained similar figures -- 0.31 and 0.46 in June in leaves from two places which increased to 1.06 and 1.26 percent respectively in September. Stems contained 0.17 and 0.18 percent in June and remained at 0.26 and 0.28 percent in, September in those areas. Shearer (3) obtained an increase from 0.28 percent in May to 0.86 in September, with a decline to 0.78 percent in October.

P_2O_5

P_2O_5 began to fall with age from 0.7 or 0.8 percent to 0.18 percent in the last stage of dying leaves. This fall is not so well-marked in the stems.

Ferguson and Armitage (1) recorded a great decrease between June and September from 1.24 to 0.17 in leaves and from 0.62 to 0.05 in stems. Russell (11) observed 0.19 and 0.11 percent P_2O_5 and mentioned that all English samples averaged 0.2 percent. (English and foreign samples taken together averaged 0.26 percent.) According:

According to Shearer (3) P_2O_5 content in May was 1.2 percent falling to 0.71 percent in June and to 0.19 percent in October. This agrees with the analyses of Scottish bracken undertaken in the present experiment.

K_2O

Since bracken has been considered a rich source of potash, K_2O has been determined and found to be between 1 and 2 percent in both leaves and stems, 81 - 89 percent of which is water-soluble.

This finding gains support from the data published by Smith and Fenton (2) who found 70 percent of K_2O to be water soluble. Ferguson and Armitage (1) obtained 3 percent of total K_2O in bracken samples. Berry, Robinson and Russell (12) gave numerous analyses of the ash of bracken at various stages of growth. About ½ (half) of the ash in young bracken consisted of K_2O whereas in fully grown material the corresponding figure was about ⅓ (a third). There is also a rapid loss of K_2O when bracken is exposed to rain.

Maxwell (10) found 4.82 percent of ash in air-dried bracken of which 41.5 percent was K_2O (i.e. 2 percent K_2O in dried fern itself). There is a considerable decrease in autumn-cut material as compared with that cut in mid-summer. Purvis (13) reported that at Cambridge:

Cambridge the percentage of K_2O in samples varied from 3 (in June) to 0.82 (in October). Russel (11), on the other hand, recorded a lower K_2O content (0.16 percent in September and 0.06 in April) in 2 samples analysed and mentioned the average of English samples as only 0.11 percent.

The figures recorded in the present experiment are similar to those observed by Shearer in England. There is a fall in October, otherwise the percentage is more or less constant at between 1 and 2. There was, however, no opportunity of examining samples obtained in May when Shearer (3) observed the highest concentration of 2.93 percent.

Though the figures quoted by various workers are variable, this is only to be expected as the composition of the soil at different places may alter the composition of the plant.

Although high, the concentration of K_2O does not seem likely to be of any significance in the production of the disease.

Chlorine

The figures for chlorine indicate the possibility of the potassium being in combination as chloride.

Protein

Bracken has generally been regarded as poor in Protein:

protein and of low digestibility. It will be observed from table No. V that the percentage of crude protein showed a remarkable decrease with growth falling from 17 to 6 percent in the leaves and from 8 to 0.3 percent in the stems. Similar decreases were noted by Smith and Fenton (2) and by Shearer (3) (21.2 percent in May to 5 percent in October). Ferguson and Armitage (1) recorded 21 percent and 16% per cent in young bracken falling as low as 3 percent in October. Hendrick (9) found the average crude protein content of 6 samples to be 4.94 percent. Thus the present figures for protein shown in table No. V agree with those recorded by other workers.

Crude Fibre

The percentage of crude fibre is ordinarily quite high, and the values of 17 to 18 percent in the leaves and 49 percent in the stems rose to 33 percent and 60 percent respectively in the very mature material. Hendrick (9) reported 22.07 to 28.25 percent in the fern while Shearer (3) obtained 15.62 percent in May increasing to 39.77 percent in October in the whole plant.

Pepsin -HCl digestion in Laboratory

The results in table No. VII show that the digestibility:

digestibility of nitrogen in bracken is poor (12 to 30 percent) as compared with a good samples of dried grass (83 percent). Mixtures of bracken and grass gave inconsistent results. With bracken (4 Lc) mixed with grass the digestibility was more or less as calculated from the two individual digestibility figures, but with bracken (10 Lc) mixed with grass there was a considerable deviation from the calculated value. In an attempt to eliminate the factor responsible for this interaction effect, samples were subjected to a preliminary water extraction but that treatment led to still greater discrepancies. When the bracken and grass were separately extracted with water before mixing, the deviations were larger than when mixture preceded the water extraction. In several cases negative digestibilities were recorded, pointing to a precipitation of the pepsin from the digestion mixture.

It is clear that the laboratory pepsin-HCl method is not satisfactory for determining the digestibility of the protein in mixtures containing bracken and it seems very likely that bracken contains some interfering substance as suspected by Ferguson and Armitage (1) who also reported inconsistent results with the pepsin-HCl method:

method of digestion. Any such interfering substance is clearly not water-soluble but it is difficult to explain the increased deviations following pre-treatment with water. Whilst the process of boiling with water may lead to protein denaturation the results suggest that in the case of grass any such denaturation did not have a pronounced effect on digestibility. With bracken the effect of the pretreatment was more marked, whilst with the mixtures of bracken and grass the effect can only be described as phenomenal.

Tannin

A qualitative test as described by Shearer (3) revealed the presence of a catechol tannin and this was therefore estimated. It will be noticed that while the concentration of tannin varied from sample to sample in the leaves, there is only a slight increase in concentration with growth. Figures as high as 4.65 percent have been recorded. A sudden increase in concentration was noted in September and a fall in October but no figures were as high as those reported by Shearer in the whole plant, viz 7.0 percent in July falling rapidly to 0.44 percent in October. It will however be noted that the method described by Rosenthaler and followed by Shearer (Hide Powder Method) (14) is generally known to give high results. As described in Chapter:

Chapter II, animal No. 2 died on 6th August and the bracken consumed by it was mainly in July when the concentration of tannin was only 2 to 3 percent in the leaves and nearly 1 percent in the stems. From the concentrations of tannin obtained in the present experiment, it is highly unlikely that this would be responsible for the disease.

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C H A P T E R IV

B. Preliminary Examination of Bracken for Toxic Constituents.

Very little attention has been directed towards the isolation and identification of any toxic material from bracken although Shearer has indicated the possibility of a toxic decomposition product of catechol tannin. As has already been shown in Section A of this Chapter, catechol tannin is present in bracken in fairly constant amount throughout the season, without showing any undue rise at any particular period, so Shearer's suggestion is not supported. It was therefore thought desirable to carryout some preliminary tests to determine the presence or absence of commonly known toxins. Powdered samples of air-dried bracken were examined in the following ways:-

Oxalic Acid

Some samples of leaves only (as these are mainly browsed under ordinary field conditions) were analysed. Oxalic acid was determined by the method of Pucher et al. (15). The concentrations found, as noted below were too low to have any practical significance, so further estimations were abandoned:-

Sample	Date of Sampling	% Oxalic Acid (on d.m. basis)
4 Lc	3.7.47	0.108
10 Lc	4.8.47	0.216
17 Lc	22.9.47	0.117
19 Lc	6.10.47	0.072

The highest concentration of oxalic acid recorded, viz 0.216 % in sample 10 Lc, would combine with an amount of CaO corresponding to 0.134% in the sample, which is only a small proportion of the total CaO (0.763%) present.

Alkaloids

The process of Stas Otto, as described by Rosenthaler (16) was used. About 150 gms. of powdered air-dried material of sample 10 Lc (the sample corresponding to the time when maximum incidence of deaths was noted - Vide Chapter II) were refluxed for ½ hour over a waterbath with alcohol slightly acidified with tartaric acid. The extract was filtered by suction and the filtrate boiled on a waterbath and distilled under partial vacuum using a "all-glass Quickfit distillation apparatus". The residue, when completely free from alcohol was extracted with distilled water, using only a very little water to begin with. The:

The water extract was generally not clear at first, so the extraction with alcohol was repeated until a clear water-extract was obtained as a final product. This extract was filtered and the filtrate subjected to the following tests:-

I) The first portion was shaken with ether to remove colouring matter as far as possible, then the ether was drawn off and the aqueous layer subjected to qualitative tests for alkaloids, with the results shown below. (17).

Test	Observation	Inference
1. Addition of Wagner's Iodine in potassium Iodide reagent	Precipitation	Presence of alkaloid.
2. Addition of Mayer's Potassium Mercuric Iodide reagent	Precipitation	Presence of alkaloid.
3. Addition of Sonneschein's Phosphomolybdic acid reagent	Precipitation	Presence of alkaloid.

Though these tests indicated the possible presence of an alkaloid, this was not conclusive as tannin and certain other substances also give positive reactions.

II) Several aliquots of the 2nd portion of the aqueous extract were evaporated to dryness on porcelain plates over:

over a waterbath. The residues were thin sticky films which were tested for alkaloids by the following colour reactions:-(18)

	Colour produced.
1. Addition of Fröhde's Reagent	Brown
2. Addition of pure conc. Sulphuric acid	Brown
3. Addition of Mandelin's Reagent	Brown

Though the colour produced in each case was dark brown, it was somewhat masked by the original dark green colour of the film. All these colour reactions suggest the presence of "Delphine" (according to chart on p. 306, Lander[17]) but as the technique of the isolation and identification of alkaloids is a highly specialised one, full confidence can not be placed in these findings which represent the results of purely preliminary examination. Nevertheless, the prosecution of more intensive work along these lines is clearly desirable.

Reinsch Test for Heavy Metallic Poisons:-

During the routine analytical investigation, the bracken samples were observed to give a peculiar greenish or bluish green ash. This colour is usually symptomatic of Manganese. As this constituent is not usually harmful to cattle, this clue was not followed up in the present investigation.

constituents.

150 gms of air-dried powdered material of several samples were examined in the following way:-

Pieces of clean copper foils were boiled in 8% HCl for ½ hour (the HCl used for preparing the solution being pure, analytical reagent); then washed and again put in a fresh supply to 8% HCl and reboiled in a thoroughly clean flask. The material under test was then introduced into the flask and boiled under a reflux condensor for 45 to 60 minutes. At the end of this period, copper foil was found to be faintly stained grey or bluish-grey. The presence of one or more of the following metals were therefore indicated - Hg, Bi, Sb, Ag, As. A similar test was carried out with hay as control and this gave negative results.

The same positive test has been obtained from the ash of the samples. The ashing was done at a low temperature in the muffle furnace. This indicated the presence of the toxic metal in the ash and that the organic constituents did not produce the stain.

No positive identification of As or Sb could be made with "Marsh test". From the colour of the stain, however, the absence of Hg or Ag could be presumed. It was thought that spectroscopic examination would reveal the identification of the metal. Unfortunately, however:

however, no arrangements for spectroscopic examination could be made and this has necessarily been postponed ~~to a future date~~.

Hydrocyanic Acid:

Only the last sample (19 Lc) was tested for hydrocyanic acid by the Sodium Picrate and Prussian blue tests. The results were negitive showing that the air-dried brown sample did not contain any hydrocyanic acid.

It may however be mentioned that recent work (19) has shown that bracken contains some hydrocyanic acid and the significance of this is now under investigation.

Table V
Chemical Composition of Bracken (Pteris Aquilina)

(Expressed as percentage of dry matter) (Organic Composition)

L E A V E S

No of Sample	Date of Sampling	Total Nitrogen	Crude Protein	Ether Extract	Crude Fibre	N.F.E.	Tannin (Catechol)
1 Lc	12.6.47	2.782	17.386	2.745	18.279	43.743	2.00
4 Lc	3.7.47	2.562	16.013	1.446	17.193	50.318	1.47
7 Lc	24.7.47	2.501	15.631	2.748	16.482	43.689	2.36
10Lc	4.8.47	2.257	14.106	1.506	26.669	38.474	2.55
13Lc	25.8.47	2.004	12.521	1.338	23.913	43.688	2.80
16Lc	15.9.47	1.301	8.130	1.310	29.641	41.703	4.65
17Lc	22.9.47	1.806	11.286	2.185	33.207	31.154	4.40
19Lc	6.10.47	1.007	6.294	1.045	32.784	41.569	2.36
			S T E M S :				
1 S_s	12.6.47	1.390	8.687	0.913	49.356	23.636	0.50
4 S_s	3.7.47	0.887	5.545	1.211	54.718	23.745	0.71
7 S_s	24.7.47	0.408	2.549	0.639	59.964	21.112	1.00
10S_s	4.8.47	0.316	1.972	0.668	59.278	22.700	1.00
13S_s	25.8.47	0.211	1.322	0.533	57.679	34.491	1.00
16S_s	15.9.47	0.208	1.031	0.619	55.004	27.594	1.00
19S_s	6.10.47	0.050	0.313	0.795	59.689	23.706	0.63

Table VI

Chemical Composition of Bracken (Pteridium Aquilina) throughout the growing season

(Expressed as percentage of dry matter)
(Inorganic composition)

No. of Sample	Date of sampling	Ash	Silica	Si free ash.	CaO	P_2O_5	K_2O	Cl	CaO / K_2O	Cl (soluble)	Solubility of K_2O
LEAVES.											
1 Lc	12.6.47	7.537	0.537	7.000	0.406	0.567					
4 Lc	3.7.47	5.558	0.685	4.873	0.402	0.735	1.373	0.511	0.293		81.64
7 Lc	24.7.47	8.198	1.110	7.088	0.639	0.818	1.433	0.705	0.446		82.70
10Lc	4.8.47	7.328	1.136	6.192	0.763	0.806		0.761			
13Lc	25.8.47	7.638	1.150	6.108	0.754	0.450	1.565	0.893	0.482		87.16
16Lc	15.9.47	6.072	1.794	4.278	0.838	0.359	1.693	0.554	0.495		
17Lc	22.9.47	7.479	2.694	4.785	1.083	0.375	1.150		0.942		
19Lc	6.10.47	5.198	1.882	3.316	0.838	0.177	0.917	0.405	0.914		88.98
STEMS											
1 S_3	12.6.47	7.154	0.369	6.785	0.250	0.454					
4 S_3	3.7.47	5.515	0.470	5.045	0.231	0.280	1.726		0.134		
7 S_3	24.7.47	5.234	1.167	4.067	0.282	0.227	1.389	0.764	0.203		86.32
10S_3	4.8.47	5.708	1.187	4.521	0.310	0.142	1.534		0.202		84.09
13S_3	25.8.47	5.959	1.473	4.486	0.405	0.167	1.465		0.276		
16S_3	15.9.47	6.781	1.807	4.974	0.400	0.114	1.615		0.248		
19S_3	6.10.47	5.781	1.130	4.651	0.295	0.201	0.917		0.332		

Table VII

Results of Laboratory Pepsin-HCl digestion of Nitrogen.

Sample	Quantity gms	Pretreatment of sample	Pepsin-insol Nitrogen	Total Nitrogen in same quantity of Org. material	Soluble Nitrogen	% N digested	Expected Digestib -ility.	Deviation from expect -ed value.
Grass	2	-	0.0103	0.0634	0.0531	+ 83.8		
Bracken 4 Lc	2	-	0.0448	0.0512	0.0064	+ 12.6		
Grass + bracken 4 Lc	1 + 1	-	0.0286	0.0573	0.0288	+ 50.2	+ 48.2	+ 4.1%
Bracken	10 Lc (2gm)	-	0.0280	0.0403	0.0123	+ 30.4		
Grass + bracken 10 Lc	1 + 1	-	0.0479	0.0518	0.0040	+ 7.6	+ 57.1	- 86.7%
Grass	1	Water-extracted	0.0050	0.0174	0.0125	+ 71.4		
Bracken 4Lc	1	Water-extracted	0.0214	0.0207	-0.0007	- 3.6		
Grass + Bradæn 4Lc	1+1	The mixture water-extracted	0.0379	0.0381	0.0001	+ 0.4	+ 33.9	- 98.8%
Bracken 10 Lc	1	Water extracted	0.0163	0.0175	0.0012	+ 6.6		
Grass and Bracken	1+1 10 Lc	The mixture water extracted	0.0407	0.0349	-0.0057	- 16.4	+ 39.0	-142.1%
Grass and Bracken 4 Lc	1+1	samples separately water extracted then mixed	0.0421	0.0381	-0.0041	- 10.6	+ 33.9	-134.2%
Grass and Bracken	1+1 10 Lc	samples separately water extracted then mixed	0.0477	0.0349	-0.0128	- 36.7	+ 39.0	-194.4%

SUMMARY:

1. The chemical composition of bracken on Hogg Hill, Buckholm farm, Galashiels, Scotland, was in agreement with the figures published by workers in other parts of the country, viz. Ferguson and Armitage (England), Shearer (England), and Smith and Fenton (Scotland).

2. The laboratory pepsin-HCl digestion of the protein in bracken gave inconsistent and unsatisfactory results, as mentioned by Ferguson and Armitage. The digestion of Nitrogen in bracken is low and there is indication of the presence of an interfering substance which is not water-soluble.

3. The theory of "Tannin Poisoning" as put forward by Shearer does not seem to be probable. The relation of a sudden high concentration in certain months to the incidence of the disease as claimed by Shearer could not be substantiated. An increase in concentration from June (2.00%) to Septemberr (4.65%) in the leaves and a practically constant concentration of 1.0 percent in the stems was noted.

4. Oxalic acid and potash contents do not seem likely to be connected in any way with the toxicity of bracken.

5. Bracken would seem to be a poor feed, especially after the month of August.

6:

6. ~~The presence of~~ An alkaloid and one or more heavy toxic metals were believed to be present ~~indicated~~ but could not be identified. The possible lines of research are thus suggested.

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C H A P T E R IV

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CHAPTER - V

C H A P T E R V.

The Nutritive Value of Bracken.

Introduction

The true nutritive value of bracken cannot be fully assessed from a routine chemical analysis. Such analyses may give a useful general idea of the variations in the value of the material at different stages of growth but the assessment of the true nutritive value requires digestibility trials with experimental animals.

No digestibility trials with bracken have been reported in the literature with the exception of the trial reported by Ferguson and Armitage (1) in 1944. It will, however, be remembered (a) that they determined the digestibility coefficient of crude protein only, obtaining a value of 53% and (b) that they used a sheep as experimental animal, a species in which "Bracken Poisoning" has never been recorded.

In view of the almost complete lack of information regarding the nutritive value of bracken, it was thought essential to carry out full digestibility trials with bullocks, using bracken at different stages of growth. The opportunity was also taken to carry-out parallel:

parallel digestibility trials with sheep for comparative purposes.

Experimental

For the collection of faeces from experimental bullocks, convenient equipment was devised employing proofed sacks held in place by light-weight webbing harness. The equipment is illustrated in Plates V, VI. (Appendix) Each sack was tied at the bottom by heavy cord, permitting the removal of faeces without unharnessing the animal. Similar equipment with small bags closed by "Zipp" - fastners was employed for digestibility trials with wether sheep (vide -IX to XII plates appendix) The bullocks were tied by the necks in stalls but the sheep were housed in special experimental cages which also permitted the collection of urine. (vide plates appendix)

In order to allow for the time taken in the passage of food through the digestive tract, the collection of faeces was made two days later than the experimental feeding Each digestibility trial extended to 12 days or more and was divided into periods of 4 days each. This enabled the seperate calculation of digestibility coefficients for each 4 day period, so that the uniformity in the digestive behaviour of the experimental:

experimental animals could be assessed.

The animals were generally fed twice daily and the faeces collected at the same times. Food residues were collected each morning. After weighing the total quantities, the samples of food, food-residues and faeces were oven-dried to determine the moisture content and the dried material preserved for analysis by the usual methods .

I Preliminary Digestibility Trials with dried mature Bracken

Investigation of the digestibility of the nutrients of bracken commenced in March 1948, when only bracken-hay made from mature foliage cut the previous October was available Although very stemmy and unpalatable this material was fed for a considerable period in order to examine its nutritive value and at the same time to determine whether it was capable of producing "Bracken Poisoning". A yearling Galloway bullock weighing approximately 5 cwts was used for the trials, which were carried out at "The Bush", Midlothian

Table VIII shows the feeding of the experimental bullock ~~animal~~ from March 6th until April 6th, when the measurement of the digestibility of a mixed ration of timothy hay and bracken commenced. This trial lasting until April 23rd For the first few days the animal was fed on chopped timothy hay only, water being allowed ad-lib. From 16th March, 1948 the animal was allowed a mixture of chopped timothy hay and chopped bracken-hay The quantity of bracken was increased gradually to determine how much could conveniently be fed along with hay. For the first 2 days, the animal did not seem to like the diet but soon:

Data for Experimental Feeding with Bracken

Date	A.M.	P.M.
6 3 48	-	3180 gms Hay (Timothy)
7 3 48	No feed	3180 gms Hay
8 3 48	3180 gms Hay	1590 gms Hay
9 3 48	1600 gms Hay	3200 gms Hay
10 3 48	3200 gms Hay	1600 gms Hay
11 3 48	3200 gms Hay	1600 gms Hay
12 3 48	No feed	3200 gms Hay
13 3 48	3200 gms Hay	No feed
14 3 48	3200 gms Hay	3200 gms Hay
15 3 48	3200 gms Hay	1600 gms Hay
16 3 48	2400 gms Hay + 200 gms Br	2400 gms Hay
17 3 48	2400 gms Hay + 200 gms Br	1200 gms Hay
18 3 48	2100 gms Hay + 300 gms Br	2000 gms Hay + 300 gms Br
19 3 48	2000 gms Hay + 300 gms Br	2000 gms Hay + 300 gms Br
20 3 48	2000 gms Hay + 300 gms Br	2000 gms Hay + 300 gms Br
21 3 48	2000 gms Hay + 300 gms Br	2000 gms Hay + 300 gms Br
22 3 48	2000gms Hay + 300 gms Br	2400 gms Hay + 400 gms Br
23 3 48	2400 gms Hay + 400 gms Br	2400 gms Hay + 400 gms Br
24 3 48	2400 gms Hay + 400 gms Br	2400 gms Hay + 400 gms Br
25 3 48	2400 gms Hay + 500 gms Br	2400 gms Hay + 500 gms Br
26 3 48	2200 gms Hay + 500 gms Br	No feed
27 3 48	2200 gms Hay + 500 gms Br	2200 gms Hay + 500 gms Br
28 3 48	2200 gms Hay + 500 gms Br	2200 gms Hay + 500 gms Br
29 3 48	2400 gms Hay + 500 gms Br	2400 gms Hay + 500 gms Br
30 3 48:		

Table VIII (con't)

Date	A.M.	P.M.
30 3 48	2400 gms Hay + 500 gms Br	2600 gms Hay + 600 gms Br
31 3 48	2600 gms Hay + 600 gms Br	2600 gms Hay + 600 gms Br
1 4 48	2600 gms Hay + 600 gms Br	No feed
2 4 48	2400 gms Hay + 500 gms Br	2600 gms Hay + 600 gms Br
3 4 48	2400 gms Hay + 500 gms Br	2400 gms Hay + 500 gms Br
4 4 48	2400 gms Hay + 500 gms Br	2400 gms Hay + 500 gms Br
5 4 48	2400 gms Hay + 500 gms Br	2400 gms Hay + 500 gms Br
6 4 48 to 23 4 48	2400 gms Hay + 500 gms Br	2400 gms Hay + 500 gms Br

soon settled down to it. It was found by trial that 1000 grms of air-dried bracken could conveniently be fed mixed with 4800 gms of timothy hay (vide Table No VIII). This therefore was the feeding given throughout the digestibility trial and for the preliminary period of 5 days preceding the trial. The hay and bracken needed for the entire digestibility trial were chopped in advance and the bracken was freed from woody stems as far as possible The daily feeds for the whole trial were then weighed out and stored in bags Aliquots from each day's feed were intimately mixed and sample taken for analysis

Results for the digestibility of this mixed ration of timothy hay and bracken hay are given in full in Appendix (Pages 8 to 10) and show that over the 16 days of the trial the digestibility of the diet was fairly uniform As corresponding figures for the digestibility of the hay alone were not available and there was insufficient hay to carry out a further digestibility trial with the bullock, it is not possible to calculate any digestibility percentages for the bracken fed A digestibility trial had however, previously been carried out with the same hay using sheep (Halfbred wethers) as experimental animals and the:

the results for the mixture of hay and bracken fed to the bullock and for the hay alone fed to the sheep are compared in Table ~~No~~ IX.

Table ~~No~~ IX

* Digestibility of Mature Bracken and Timothy Hay*

Animal	Ration	% Digestibility				
		D.M.	C.P.	E.E.	C.F.	N.F.E.
Bullock	17% bracken D M ± 83% hay D M.	55	50	35	51	59
Sheep	100% hay	53	39	Nil	49	59

These figures suggest that the constituents of the bracken were fully as digestible as those of the hay, but as the bracken constituted only a small proportion of the total feed any conclusion drawn from these data can only be tentative.

When the animal had become more accustomed to the bracken this was fed separately from the hay, without chopping, but the stems were first removed by hand-picking. In order to increase the consumption of bracken, the amount of hay fed was kept low. As a result the bullock was losing condition, but consuming a ration containing approximately 38% of bracken and 62% of Ryegrass seeds-hay. The digestibility of the ration:

ration was then determined over a period of 12 days (vide appendix pages 14 to 17, Experiment III) and was followed by a further 12 days trial in which only the hay was fed (vide appendix pages 11 to 13 Experiment II) In table No X are shown the average digestibility percentage for the mixture of Ryegrass hay and bracken and for the hay alone as well as the corresponding values calculated for the bracken alone.

Table No X

*Digestibility of mature bracken and Ryegrass hay

Ration	% Digestibility					
	D.M.	Org.M.	C.P.	E.E.	C.F.	N.F.E.
38% Bracken + 62% Ryegrass hay	43.32	44.84	27.72	29.85	44.86	48.01
Ryegrass Hay	54.0	56.1	35.9	42.0	63.7	52.4
Bracken (calculated)	24.8	25.6	16.6	12.8	11.9	40.2

These calculated digestibility percentages for the bracken fed are much more in accordance with expectations than were the indications of Table No. IX and it is clear that when appreciable amounts of bracken are consumed the digestion is poor, particularly in the case of Crude Protein and Crude Fibre. Values for:

for the crude nutrients, digestible nutrients and starch-equivalent of the mature bracken-hay are summarised in Table No. XI

Table No XI

Composition and Nutritive Value of mature-bracken hay

(Expressed as % in dry matter)

	Total	Digestible
Crude Protein	8.59	1.43
Ether Extract	1.41	0.18
Crude Fibre	40.15	4.77
N.F.E.	44.75	17.98
S.E. (per 100 lb)		1.14 *

* The "Starch Equivalents" have been calculated in the usual way from % digestible nutrients but have not been increased by $^1/_5$ th as is now usually practised to bring the results in line with Armsby's findings .

It is clear that this bracken is of extremely low nutritive value containing only 1.43% digestible protein and having a starch equivalent of only 1.14. In fact the nutritive value is for all practical purposes, nil and the inclusion of this material in the ration merely served to give bulk to the diet. It is not surprising, therefore, that the animal lost condition:

condition during this period, when the amount of hay fed (less than 5 lb daily) was necessarily kept below maintenance level.

During the preliminary feeding trials the experimental animal consumed only bracken and hay for almost 3 months (16.3.48 to 4.6.48) without showing any symptoms except slight undernutrition. Nevertheless this same animal was later found to succumb to bracken poisoning after about 1 month's feeding on fresh bracken, (Vide Plates II, III, IV, Appendix) so it must be concluded that the toxic principle in the old dried bracken was either absent or only present in very small quantity. This might result from losses by rain-washing or volatilisation during the field-drying process or it may be that the amount of active constituent in the plant declines with advancing maturity.

II The Nutritive Value of Fresh Bracken - In July 1948

The digestibility trials with fresh bracken were carried out at Buckholm farm, Galashiels, using two Irish bullocks and two halfbred wethers. As a supply of baled Lothian seeds-hay was to be used to supplement the ration, the digestibility of this had first to be determined. The results obtained for this hay are given in Appendix (Pages 18 - 21, experiment IV) and Appendix (pages 22 to 26 Experiment V), and are summarised in Table ~~No~~ XII.

The results for the two bullocks show close agreement and those for the two sheep are also in line but the two sets of average figures show the bullocks to possess appreciably superior digestive ability in dealing with this hay. Thus the hay had a decidedly higher nutritive value for the bullocks than for the sheep as shown in table ~~No~~ XIII.

For the bracken feeding trials fresh green bracken at a medium stage of growth was cut daily and brought down the hill to the farmstead where the experimental animals were housed. Weighed amounts were fed to the sheep and bullocks in 3 feeds at 10 a m , 1 p.m. and 4 p.m. By 5.30 p.m. most of the bracken fed to the bullocks had been consumed, so they were then given 3 Kg.

Table No XII

% Digestibility of Seeds Hay used as Supplement to bullocks.

Animals	Dry Matter	Org Matter	Crude Protein	Ether Extract	Crude Fibre	N.F.E.
Bullock No 1	58 9	61.0	49.1	57.3	69.4	55.5
No 2	60.5	62.4	49.7	61.4	70.4	57.5
Average for Bullocks	59.7	61.7	49.4	59.4	69.4	56.5
Sheep A	47.5	49.4	41.9	57.7	57.7	42.8
Sheep B	50.6	52.5	44.9	57.6	58.8	47.7
Average for Sheep	49.1	51.0	43.4	57.7	58.3	45.3

Table No XIII

Nutritive value of Seeds Hay (Expressed as Percentage of Dry Matter)

Nutrients		Total Digestible	
		For Bullocks	For Sheep.
Crude Protein %	7.87	3.89	3.42
Ether Extract %	2.08	1.23	1.20
Crude Fibre %	39.46	27.58	23.00
N. F. E. %	42.68	24.10	19.30
S. E. (lb per 100 lb)		34.79*	25.14*

* The starch equivalents have been calculated in the usual way from % digestible nutrients but have not been increased by 1/5th as is now usually practised with hay and straw to bring the results in line with Armsby's findings.

3 Kg hay (fresh weight). Any residual bracken was mixed with this hay and so largely eaten up. The food residue was collected the following morning and the bracken separated from the hay and stored separately for analysis.

The sheep were each given 4 Kg of bracken daily (fresh Wt) and were found to consume sufficient to make a hay supplement unnecessary.

Whilst the bullocks ate almost everything, the sheep were found to leave the bracken stalks to some extent, preferring the leaves.

Full results of these digestibility trials may be found in Appendix (Bullocks Pages 27 to 32 Expt VI and Sheep pages 33 to 37 Experiment VII) but the average figures are summarised in Table No XIV.

The figures for bullocks 1 and 2 agree quite well except for the Ether Extract and Crude fibre fractions. The differences in fibre digestibility are most important and are probably due to difference in the amount of fibrous bracken stem eaten by the two bullocks. This is borne out by the analyses of the bracken residues, shown in Appendix (Page 28) since the fact that residues left by bullock No 1 were richer in fibre than those left by bullock No 2 indicates that bullock No. 1 ate less fibrous stem than the other. These same:

Table ~~No~~ XIV

The Digestibility of Bracken in July.

Ration	Dry Matter	Org. Matter	Crude Protein	Ether Extract	Crude Fibre	N.F. E.
Bullock No 1 Exp VI						
Bracken + Hay	58.3	59.7	43.1	48.4	60.8	63.7
Hay	58.9	61.0	49.1	57.3	69.4	55.5
Bracken (calculated)	57.9	58.9	41.2	44.3	52.6	68.1
Bullock No 2 Exp VI						
Bracken + hay	58.1	59.6	45.8	57.5	56.8	64.6
Hay	60.5	62.4	49.7	61.4	70.4	57.5
Bracken (calculated)	56.6	57.8	44.6	55.7	43.2	68.8
Average Digestibility for Bullocks						
Bracken (calculated)	57.2	58.4	43.0	50.0	47.9	68.5
Sheep A Exp VII						
Bracken	51.1	52.6	31.3	57.5	43.8	62.0
Sheep B Exp VII						
Bracken	57.9	58.9	42.8	62.5	47.7	68.0
Average Digestibility for Sheep						
Bracken	54.5	55.8	37.0	6D.0	45.8	65.0

analyses also indicated that bullock No 2 consumed less Ether Extract than bullock No 1 which may account for the big difference in Ether Extract digestibility.

The digestibility figures for Sheep B are in close agreement with the averages for the two bullocks, except for ether extract whilst Sheep A showed apparently lower digestibility of all fractions. Previous work with 2 sheep indicated that sheep A had consistently lower digestive ability than sheep B and was much more liable to sporadic loss of appetite.

In table ~~No~~ XV is shown the nutritive value of the bracken calculated from the average digestibility percentages in Table XIV.

Table ~~No~~ XV

Nutritive Value for bracken in July
(Expressed as % dry matter)

Nutrients	Total	Digestible	
		For Bullocks	For Sheep
Crude Protein%	14.01	6.01	5.19
Ether Extract%	2.88	1.44	1.73
Crude Fibre%	27.23	13.04	12.47
N.F.E.%	49.70	34.01	32.31
S.E. (lb per 100 lb)	-	39.65	37.14

As:

As the bullocks were each in the region of 700 lb live-weight they would require, approximately 0.42 lb of "digestible crude protein" and 4.5 lb. of "starch equivalent" daily, for maintenance. From the "digestible crude protein" and "starch equivalent" values shown in Tables XIII (May) and XV (July bracken) it has been calculated that the average daily consumption of 2.61 Kg hay dry matter and 4.09 Kg bracken dry matter provided 0.77 lb of "digestible crude protein" and 5.6 lb of "starch equivalent". Thus the animals were receiving during this period a super-adequate diet with quite a high level of digestible crude protein. The sheep, which were of approximately 80lb bodyweight would, according to Woodman's (2) standards require for maintenance a daily intake of 0.05 lb "digestible crude protein" and 1.11 lb "starch equivalent". As the average daily consumption of bracken dry matter was, however, only 7-37 gms. this would provide 0.085 lb "digestible crude protein" but only 0.61 lb "starch equivalent". The diet of the sheep was therefore inadequate in respect of "Starch equivalent"

III The Nutritive Value of fresh Bracken - In August 1948

The fresh green bracken at a later stage of growth was fed in the same manner as before, and the same Lothian's Seeds Hay used as supplement. As the bracken was more woody and dry, the consumption was less than in July but it was still possible to feed it in sufficient quantity to the sheep to make the hay supplement unnecessary

The detailed results given in Appendix (Bullocks pages 38 to 42 Exp VIII and Sheep (pages 43 to 47 Exp IX) are summarised in Table XVI.

Digestibilities for bullocks 1 and 2 show good agreement except for the carbohydrate fractions The analyses of the food residues (Appendix page 39 ExpVIII) suggest that bullock No 1 consumed more bracken fibre than bullock No 2 and this may account for the lower fibre digestibility with No 1. It does not, however, account for the higher digestibility of the N.F.E. by bullock No 1, although, being calculated by difference, the N.F.E. figures are obviously the least reliable.

The results for the two sheep show closer agreement than in July and the differences between the sheep and bullocks are relatively small. The nutritive value of:

Table No. XVI

The Digestibility of Bracken in August-

Ration	Dry Matter	Organic Matter	Crude Protein	Ether Extract	Crude Fibre	N.F.E.
Bullock No 1						
Bracken + Hay	55.0	56.5	29.0	68.2	56.8	60.8
Hay (Exp IV)	58.9	61.0	49.1	57.3	69.4	55.5
Bracken (calculated)	52.6	53.7	18.8	75.9	43.6	66.4
Bullock No 2 (Exp VIII)						
Bracken + Hay	54.0	55.4	28.0	72.5	58.9	57.2
Hay (Exp IV)	60.5	62.4	49.7	61.4	70.4	57.5
Bracken (calculated)	49.8	50.9	17.8	78.4	49.0	57.3
Average Digestibility for Bullocks						
Bracken	51.2	52.3	18.3	77.2	46.3	61.9
Sheep A Exp IX						
Bracken	49.7	51.0	19.4	74.4	52.0	55.6
Sheep B Exp IX						
Bracken	47.6	48.4	24.5	77.7	47.2	52.6
Average Digestibility for Sheep						
Bracken	48.7	49.7	22.0	76.1	49.6	54.1

of the August bracken, calculated from these figures, is shown in Table No XVII.

Table XVII

Nutritive Value of Bracken in August (Expr.% D.M.)

Nutrient	Total	Digestible For Bullock	Digestible For Sheep
Crude Protein%	9.43	1.73	2.07
Ether Extract%	2.54	1.93	1.4
Crude Fibre%	35.53	16.45	17.62
N.F.E. %	46.94	29.03	29.01
S.E. (lb per 100 lb)	-	30.16	30.61

When consuming an average daily intake of 3.47 Kg dry matter from August-bracken and 2.64 Kg dry matter from hay, the bullocks were receiving inadequate amounts of "digestible crude protein" (0.38lb) and "starch equivalent" (4.3 lb). With sheep also, consuming an average of 612 gms of bracken - dry matter, the daily intakes of "digestible crude protein" (0.03 lb) and "starch equivalent" (0.41 lb) were both less in August than in July and both below maintenance level, the deficiency being particularly marked in the case of "starch equivalent"

Table No XVIII

see over -

Table No XVIII

Comparative Nutritive Values.

(% in Dry Matter)

	Digestible Crude Protein	Starch Equivalent
Mature Pasture Grass (in full flower) (3)	5.2	51.2
Seeds Hay (vide table No XIII)	3.65 Average figures for bullock and sheep	30.0+ ×
Bracken (July)	5.60	38.4
Bracken (August)	1.90	30 4

+ 34.8 for bullock
25.1 for sheep

×(The starch equivalent has been calculated in the usual way from % digestible nutrients but have not been increased by 1/5th as is now usually practised with hay and straw to bring the results in line with Armsby's findings.)

It will appear from t-able ~~No~~ XVIII that bracken in July compares favourably with mature pasture grass as far as digestible crude protein is concerned but contains far less starch equivalent. It is more comparable with seed-hay in nutritive value, being possibly somewhat superior in digestible protein.

In:

In August, however, the bracken contains much less digestible crude protein whilst the starch-equivalent is also somewhat reduced. Although the "starch-equivalent" value may still be comparable with hay the "digestible crude protein" content in August is probably more like that of straw than of hay.

IV Nitrogen Balance Data (Sheep)

As the experimental sheep were housed in cages permitting the quantitative collection of urine, it was possible to determine the nitrogen balance with these animals. The data obtained are given in Table ~~IXX~~ XIX.

Whilst the short period of time for which these balances were calculated renders the results of limited value, it is clearly significant that the balances were in practically all cases negative and much more so in the case of the August bracken than with the July bracken. These results support the conclusions drawn from Tables XV and XVII that whilst the protein nutrition of sheep in July was probably adequate, it was decidedly inadequate in August.

Summary

(a) The mature dried bracken-hay is of extremely low nutritive value, containing only 1.43% digestible crude protein and having a starch equivalent of only 1.14.

(b) As expected, the digestibility of fresh green bracken in July is better than bracken-hay. The nutritive value is comparable to that of seeds-hay

(c)

Table ~~No~~ ~~IXX~~ XIX

N Balance Data for bracken-fed Sheep.

		Nitrogen Consumed. (gm)	Nitrogen in faeces (gm)	Nitrogen in Urine (gm)	Total Nitrogen excreted (gm)	Nitrogen Balance
				Sheep A		
July	Total (8days)	127.3	90.8	32.1	122.9	+ 4.4
Bracken	Average/day	15.9	11.4	4.0	15.4	+ 0.55
				Sheep B		
	Total (4 days)	57.9	42.4	20.6	63.0	- 5.1
	Average/day	14.5	10.6	5.2	15.8	- 1.28
				Sheep A		
August	Total(12days)	118.4	95.4	58.6	154.0	-35.6
Bracken	Average/day	9.9	8.0	4.9	12.8	- 2.97
				Sheep B		
	Total(12days)	129.2	97.6	79.6	177.2	-48.0
	Average/day	10 9	8.1	6.6	14.8	- 4.00

(c) The digestibility of green bracken in August is lower than that of July and it is decidedly poorer in nutritive value. The "digestible crude protein" content nearly approaches that of the dried bracken-hay. The "starch equivalent" though far less than that of mature pasture grass, is still comparable to seeds-hay.

(d) There is no significant difference in digestibility of bracken by sheep and bullock.

(e) After the month of July, bracken is very poor feed. The low "digestible crude protein" in the bracken diet may be an important factor in predisposing an animal to "bracken poisoning"

References

1 Ferguson W S and Armitage E R (1944) J Agric Sci 34, 165

2 Woodman H E. (1948) Min Agric. Fish. Bull. No 48 page 78.

3 Watson S J. (1948) "Feeding of Livestock" Nelson's Agric Series. Thomas Nelson and Sons, Edinburgh.

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General Summary

1 The review of t-he literature shows divergencies of opinion regarding Bracken Poisoning.

2 (Pilot Experiment 1947) Experimental feeding of green bracken at a rate of 40 lb fresh weight daily produced Bracken Poisoning in bullocks. The symptoms and post-mortem pictures are described.

3 No significant variation in the ordinary constituents of blood could be traced on routine blood analyses of animals during the course of feeding or during the course of the disease

4. The chemical composition of bracken during the growing season afforded no clue. Tannin, as a possible toxic principle was not present in a very high concentration in bracken fed. Thus, Shearer's suggestion could not be substantiated.

The digestion of protein, as determined by pepsin-HCl method in the laboratory, gave low and negetive results.

The preliminary examination of bracken indicated the necessity of further specialised work on alkaloids and toxic trace metals.

5 The digestibility of various constituents in bracken (as determined by digestibility trials on bullocks and sheep).

(continued overleaf)

shows it to be of low nutritive value. There is a highly significant decrease in crude-protein digestibility from July to August The bracken-hay is of extremely low nutritive value, which is nil for all practical purposes.

The lower digestibility of protein possibly indicates that the toxic substance, if any, is not present in this fraction.

The low protein digestibility may be a factor in precipitating the symptoms of "Bracken Poisoning".

ACKNOWLEDGEMENT.

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My thanks are also due to Dr Greig, Dr Stewart of The Animal Diseases Research Association and Dr A M Smith of the Edinburgh and East of Scotland College of Agriculture, for kindly providing laboratory facilities.

APPENDIX

TABLE I

PROTHROMBIN AND CLOTTING TIME OF BLOOD OF EXPERIMENTAL ANIMALS.

Date	Animal No.1		Animal No.2		Animal No.3		Animal No.4		Animal No.5		Animal No.6	
	Prothrombin time at 37°C	Plasma Clotting time at 37°C	Prothrombin time at 37°C	Plasma Clotting time at 37°C	Prothrombin time at 37°C	Plasma Clotting time at 37°C	Prothrombin time at 37°C	Plasma Clotting time at 37°C	Prothrombin time at 37°C	Plasma Clotting time at 37°C	Prothrombin time at 37°C	Plasma Clotting time at 37°C
7.8.47	12".2	3 -25"	-	-	13.4"	1 -58"	21.0"	5 -41"	-	-	-	-
11.8.47	14".0	1 -18"	-	-	12.1"	1 -19"	11.3"	0 -58"	-	-	-	-
25.8.47	15".0	1 -7"	-	-	12.5"	0 -25"	12.0"	1 -0"	-	-	-	-
1.9.47	13".9	1 -40"	-	-	15.4"	1 -45"	14.4"	1 -30	-	-	-	-
8.9.47	-	-	-	-	13.05"	1 -0	-	-	-	-	-	-
8.9.47	-	-	-	-	-	-	11.3"	0 -52	-	-	-	-
15.9.47	-	-	-	-	-	-	11.1"	0 -30	12"	0 -30"	-	-
22.9.47	-	-	-	-	-	-	13.2"	1 -3	13.8"	1 -3"	11".8	1 -10"
29.9.47	-	-	-	-	-	-	13.0"	1 -10	12.2"	1 -5"	11".6	0 -49"
6.10.47	-	-	-	-	-	-	12.6"	0 -58"	10.0"	1 -16"	13".3	1 -2"

With the help of the Veterinary Department of the Edinburgh and East of Scotland College of Agriculture

Post-Mortem Examination Results

I Animal No. 2: Post mortem examination on 7.8.47 at Moredun A.D.R.A.

Observations: clinical signs: The animal was noticed to be feeding poorly on the 5th August.

symptoms: Salivation, blood stained and frothy discharge from the nostrils, and voiding of frequent small quantity of faeces. The animal was very tucked up and unsteady. Mucous membrane - pale: Conjunctive - slightly infected: Respirations - hurried and laboured: Pulse - not readily perceptible and very fast: Temperature - 106°F. The animal grunted when turned quickly.

The animal died on the evening of the 6th August 1947 and was post-mortemed on the morning of the 7th August. Considerable post-mortem change had taken place making it impossible to notice any slight changes in the tissues. The most marked lesions were in the abomasum where multiple haemorrhages were seen in the mucous membrane - particularly at the pyloric area. The omasum was markedly impacted. Petechiae were visible in the nasal mucous membrane and the bronchus. Petechiae and haemorrhages were present in the endocardium and myocardium. Tissues were not fit for histological or bacteriological examination. There was:

was considerable gelatinous oedema in the area between the rami of the mandible and the masculature of the base of the tongue was blackened. This lesion extended right through the tongue tissues.
N.B. The animal's carcase had been pulled on to the lorry by means of a rope attached round the neck.

II Animal No. 3: Roan bullock (2nd group).

The animal was shot and bled before examination. The carcase was in moderate condition.

Digestive System

(a) Abomasum - Numbers of small irregular depressed ulcers (up to 5 m.m. diameter) with haemorrhagic floors and pale borders were scattered over the mucosa of the folds of the Fundus region.

In the Pyloric region, small pale cicartriecs were noted in the mucosa with, occassionally, ulcers similar to those of the Fundus region but in the process of healing.

(b) Small Intestine: An occasional small ulcer was present in the mucosa throughout the length of the small intestine. In the terminal portion of the Ileum however, adjoining the Ileo-Caecal valve, a few large, depressed haemorrhagic ulcers (up to 1.5 cm. diameter) were noted and some were confluent with the ulcerated and:

and necrotic mucosa of the valve itself. The inflamatery precess in this region extended through the intestinal wall resulting in a severe localised peritonities with adhesions.

The lumen of the Ileo-Caecal valve was markedly constricted and the findings in this region suggested that rupture of the Ileum might have occured just anterior to the valve some time previously.

(c) Caecum: Adjoining the Ilea-Caecal Valve and the Caeco-Colic Orifice, further ulcerated areas in the mucosa were noted and the wall of the caecum in this region was much thickened and eadematous. A necrotic slough (6 c.m. × 3 c.m.) was found free in the lumen apparently composed of shreds of mucosa intermingled with food material. Towards the apex of the caecum, the mucosal folds showed small irregular haemorrhagic blotches scattered over them.

The regional lymph nedes were enlarged and oedematous.

(d) Colon: The mucosa showed longitudinal haemorrhagic streaks.

(e) Liver: The liver substance was pale and rather mottled. Two adult flukes were present.

Circulatory System.

Pronounced streaky haemorrhages were present beneath:

beneath the endocardium of both ventricles of the heart.

Other tissues

No abnormalities.

III Animal No. 1: Post-Mortem: Subcutaneous and intramuscular haemorrhages were present throughout the body specially marked on the shoulders and neck.

Digestive System: Small haemorrhages were present throughout the length of the oesophagus, both in the muscle and submucosa.

Rumen etc. Large blood splashes were present beneath the visceral poritoneum and in the wall of the rumen. The same picture was presented by the reticulum. The omasum was extremely distended and impacted and the superiteneal haemorrhages practically covered the surface of the organ.

Abomasum. The abomasum contents consisted of blood clot only and the mucous membrane was covered with haemorrhages of the size of a silver threepenny piece. These haemorrhages were especially marked at the pyloric area of the abomasum.

Small Intestine. The peritoneal surface of the small intestine was covered by haemorrhages throughout its length. A large submucous haemorrhage extended from the:

the pyloric sphimeter down the first two feet of intestine and was followed by smaller haemorrhages and blood splashes. No ulceration was present. The bowel contents were mostly blood clots.

Large Intestines. A similar picture was presented by the large intestine but the reaction was more marked, the entire mucosa being of a deep port-wine colour while the mucous folds were deeply engorged giving a purple "striping" effect.

Caecum. The caecum was contracted to an external diameter of about one inch completely occluding the lumen where engorgement and extravasation were only shown on the ridges of the folds of mucous membrane.

Liver. The liver appeared fatty and friable and numerous pin-head extravasations were present beneath the peritoneum and throughout the liver substance. The gall bladder was distended and the contents blood-stained.

Kidneys. Presented a similar picture to the liver.

Bladder. Haemorrhages were present on mucous and peritoneal surfaces and throughout the muscle wall.

Respiratory System. Petechae were present in the nasal mucous membrane and throughout the bronchi. The lungs showed no microscopic lesions. Large haemorrhages were:

were present in the subpleura.

Circulatory System. Large splashes were present in the walls of all the large vessels in the heart muscle and sub-endocardium. A large amount of haemorrhage had taken place between the layers of the peritoneum.

Cultures. Aerobic and anaerobic cultures from bone-marrow and spleen remained sterile.

Experiment I — Digestibility of Timothy hay + bracken hay by Bullock (1 yr old galloway)

Period	Dates Feeding	Dates Faecal Collection	No. of Days	Food Fed Fresh Wt Hay	Food Fed Fresh Wt Brack.	Food Fed Dry Wt. Hay	Food Fed Dry Wt. Brack.	Food Residues Fresh Wt. H + B	Food Residues Dry Wt. H + B	Food Consumed Fresh Wt. H + B	Food Consumed Dry Wt. H + B	Faeces Fresh Wt.	Faeces Dry Wt.
I	6.4.48-9.4.48	8.4.48-11.4.48	4	19,200	4,000	15,830	2,920	3411	2504	19,789	16,246	42,130	8,050
II													
II	10.4.48-13.4.48	12.4.48-15.4.48	4	19,200	4,000	15,710	2,900	1926	1385	21,274	17,225	38,570	7,950
III	14.4148-17.4.48	16.4.48-19.4.48	4	19,200	4,000	15,780	2,900	1338	981	21,862	17,699	39,660	8,000
IV	18.4.48-21.4.48	20.4.48-23.4.48	4	19.200	4,000	15,600	3,060	1141	806	22,059	17,854	38,880	7,900

H = Hay

B = Bracken.

Experiment I

Analyses (% in dry matter)

Constituents	Timothy hay fed Period I	II	III	IV	Bracken fed I	II	III	IV	Food Residue (H+B) I	II	III	IV	Faeces I	II	III	IV
Ash	5.04	4.77	5.03	6.17	5.07	5.06	5.27	5.30	5.78	7.80	10.25	8.49	7.20	7.29	7.13	7.63
Org. matter	94.96	95.23	94.97	93.83	94.93	94.94	94.73	94.70	94.22	92.20	89.75	91.51	92.80	92.71	92.87	92.37
Crude protein	6.28	6.20	6.11	7.26	6.37	5.80	6.29	5.94	5.27	5.51	6.45	6.25	6.88	7.30	7.02	6.93
Ether extract	1.52	1.54	1.31	1.29	1.05	1.03	1.18	1.17	1.09	1.48	1.65	1.78	1.83	1.93	1.99	1.90
Crude Fibre	35.66	35.69	36.09	34.96	49.89	45.70	43.35	44.83	41.58	39.66	38.43	39.59	40.57	40.07	38.82	37.89
N-free extract	51.50	51.80	51.46	50.32	37.62	42.41	43.91	42.76	46.23	45.55	43.22	43.89	43.52	43.41	45.04	45.65

Experiment I Digestibility of Timothy Hay and Bracken Hay

	D.M.	Or.M.	C.P.	Ether Extract	C.F.	N.F.E.
PERIOD I						
Hay fed	15830	15032.4	944.26	240.62	5645.2	8152.7
Bracken fed	2920	2772.0	185.99	30.66	1457.2	1098.5
Total fed	18750	17804.4	1180.25	271.28	7102.4	9251.2
Rood Residue	2504	2359.4	131.95	27.30	1041.1	1158.8
Consumed	16246	15445.0	1048.30	243.99	6061.3	8092.4
Faeces	8050	7471.4	553.87	147.33	3265.9	3503.5
Digested	8196	7973.6	494.43	96.66	2795.3	4588.9
% Digestibility	50.4	51.6	47.16	39.62	46.12	56.7
PERIOD II						
Hay fed	15710	14961.1	974.08	241.94	5606.98	8137.8
Bracken fed	2900	2753.5	168.19	29.87	1325.2	1229.9
Total fed	18610	17717.6	1142.27	271.81	6932.18	9367.7
Food Residue	1385	1277.0	76.32	20.50	549.28	630.9
Consumed	17225	16437.6	1065.95	251.31	6382.90	8736.74
Faeces	7950	7370.6	580.37	153.43	3186.0	3451.4
Digested	9275	9067.0	485.58	97.88	3196.9	5285.34
% Digestibility	53.8	55.1	45.56	38.95	50.1	60.4972
PERIOD III						
Hay fed	15780	14986.0	964.27	20673	5695.1	8120.7
Bracken fed	2900	2747.1	182.43	34.22	1257.1	1273.5
Total fed	18680	17733.1	1146.70	240.95	6952.2	9394.2
Food Residue	981	880.4	63.27	16.19	377.0	424.0
Consumed	17699	16852.72	1083.43	224.76	6575.2	8970.2
Faeces	8000	7429.60	561.60	159.20	3105.6	3603.2
Digested	96.99	9423.12	521.83	65.56	3469.6	5367.0
% Digestibility	54.8	55.92	48.17	29.17	52.78	59.83
PERIOD IV						
Hay fed	15600	14637.0	1132.7	201.23	5453.8	7850.6
Bracken fed	3060	2897.8	181.8	35.81	1371.8	1308.5
Total fed	18660	17534.8	1314.5	237.04	6825.6	9159.1
Food Residue	806	737.6	50.38	14.35	319.1	353.8
Consumed	17854	16797.2	1264.12	222.69	6506.5	8805.3
Faeces	7900	7297.3	547.48	150.10	2993.4	3606.4
Digested	9954	9499.9	716.64	72.59	3513.1	5198.9
% Digestibility	55.8	56.34	56.70	32.76	53.989	59.05

Experiment II — Digestibility of Ryegrass Seeds Hay by Bullock (1yr old galloway)

Period	Dates Feeding	Dates Faecal Collection	No. of days	Food - Fed Fresh Wt. Hay	Food - Fed Dry Wt. Hay	Food Residues Dry Wt	Food Consumed Dry Wt.	Faeces. Fresh Wt.	Faeces. Dry Wt.
I	8.6.48-11.6.48	10.6.48-13.6.48	4	16,000	13,440	Nil	13,440	33,205	6,160
II	12.6.48-15.6.48	14.6.48-17.6.48	4	16,000	13,440	Nil	13,440	33,899	5,900
III	16.6.48-19.6.48	18.6.48-21.6.48	4	16,000	13,440	Nil	13,440	32.140	6.340

Experiment II — Analyses (% in dry matter) — Digestibility of Ryegrass Seeds Hay

Constituents	Hay Fed Periods I, II + III	Food Residue	Faeces I	Faeces II	Faeces III
Ash	5.94	Nil	9.16	9.65	9.41
Org. Matter	94.06	Nil	90.84	90.35	90.59
Crude Protein	6.53	Nil	9.53	9.56	8.45
Ether Extract	1.38	Nil	1.75	1.69	1.82
Cr. Fibre	41.16	Nil	33.20	31.61	33.44
N. F. E.	44.99	Nil	46.36	47.49	46.88

Experiment II Digestibility of Ryegrass Seeds Hay by Bullock

PERIOD I

	D.M.	Or.M.	C.P.	E.E.	Cr.F.	N.F.E.
Hay Fed	13,440	12643	877.7	185.47	5532.0	6047.1
Total fed	13,440	12643	877.7	185,47	5532.0	6047,1
Food Residue	Nil	Nil	Nil	nil	Nil	Nil
Consumed	13,440	12643	877.7	185.47	5532.0	6047.1
Faeces	6160	5596	587.0	107.81	2045.1	2855.7
Digested	7280	7047	290.6	77.663	3486.9	3191.3
% Digestibility	54.16	55.85	33.11	41.87	63.04	52.87

PERIOD II

Hay Fed	13,440	12643	877.7	185.47	5532.0	6047.1
Total fed	13,440	12643	877.7	185.47	5532.0	6047.1
Food Residue Consumed	Nil	Nil	Nil	Nil	Nil	Nil
Faeces	5900	5330	564.1	99.710	1865.1	2801.9
Digested	7540	7312.	313.6	85.758	3666.9	3245.1
% Digestibility	55.11	57.84	35.74	46.24	66.28	53.67

PERIOD III

Hay fed	13,440	12642.6	877.6	185.47	5532.0	6047.1
Total fed	13,440	12642.6	877.6	185.47	5532.0	6047.1
Food Residue Consumed	Nil	Nil	Nil	Nil	Nil	Nil
Faeces	6340	5743.4	535.72	115.40	2120.2	2972.4
Digested	7100	6899.2	341.93	70.07	3411.8	3074.7
% Digestibility	52.83	54.59	38.96	37.78	61.67	50.85
Overall Digestibility	54.03	56.06	35.93	41.96	63.66	52.43

Experiment III — Digestibility of Ryegrass Hay and Bracken hay by Bullock (1 yr old Galloway)

Period	Dates Feeding	Dates Faecal Collection	No. of days	Food Fed Fresh Wt. Hay	Food Fed Fresh Wt. Brack	Food Fed Dry Wt. Hay	Food Fed Dry Wt. Brack	Food Residues Fresh Wt. H * B	Food Residues Dry Wt. H * B	Food Consumed Fresh Wt. H * B	Food Consumed Dry Wt. H * B	Faeces Fresh Wt.	Faeces Dry Wt
I	22.5.48-25.5.48	24.5.48-27.5.48	4	8000	6000	6768	5010	nil 1203	nil 935	8000 4797	6768 4075	29,620	6,040
II	26.5.48-29.5.48	28.5.48-31.5.48	4	8000	6000	6768	5010	nil 1919	nil 1516	8000 4081	6768 3494	31,780	6,180
III	30.5.48-2.6.48	1.6.48-4.6.48	4	8000	6000	6768	5010	nil 1212	nil 915	8000 4788	6768 4095	28,614	5,880

H = Hay
B = Bracken.

Experiment III — Analyses (% in dry matter) Digestibility of Ryegrass hay+bracken hay by bullock

Constituents	Hay fed Period I,II,III	Bracken Fed I, II,III	Food Residue Bracken only. I	II	III	Faeces. I	II	III
Ash	5.52	5.10	5.25	4.68	5.12	8.35	8.07	7.43
Org. Matter	94.48	94.90	94.75	95.32	94.88	91.65	91.93	92.57
Crude Protein	7.12	8.59	6.83	6.80	7.31	10.16	9.76	10.03
Ether Extract	1.19	1.41	1.29	1.24	1.14	1.81	1.50	1.48
Crude Fibre	37.41	40.15	55.41	51.65	49.77	33.87	37.48	36.88
N. Free Extractives	48.76	44.75	31.22	35.63	36.66	45.81	43.19	44.18

Experiment III Digestibility of Ryegrass Hay and Bracken Hay

PERIOD I

	D.M.	Or.M.	C.P.	E.E.	Fibre	N.F.E.
Hay fed	6768	6394	481.9	80.54	2532	3300.0
Bracken fed	5010	4754	429.9	70.65	2011	2242.0
Total fed	11778	11149	911.8	151.19	4544	5542.1
Food residue	935	886	63.9	12.06	518	292.0
Consumed	10843	10263	847.9	139.13	4026	5250.1
Faeces	6040	5536	613.6	109.37	2046	2766.9
Digested	4803	4726	234.3	29.76	1980	2483.3
% Digestibility	44.30	46.01	27.57	21.39	49.20	47.29

PERIOD II

	D.M.	Or.M.	C.P.	E.E.	Fibre	N.F.E.
Hay fed	6768	6394	481.9	80.54	2532	3300.1
Bracken fed	5010	4755	429.9	70.65	2011	2242.1
Total fed	11778	11488	911.8	151.18	4544	5542.1
Food residue	1516	1445	103.1	18.79	783	540.1
Consumed	10262	9703	808.7	132.39	3761	5001.9
Faeces	6180	5682	603.2	92.70	2316	2669.1
Digested	4082	4022	205.5	39.68	1444	2332.8
% Digestibility	39.78	41.45	25.41	29.98	38.42	46.64

PERIOD III

	D.M.	Or.M.	C.P.	E.E.	Fibre	N.F.E.
Hay fed	6768	6394	481.9	80.54	2532	3300.1
Bracken fed	5010	4754	429.9	70.65	2011	2242.1
Total fed	11778	11148	911.81	151.18	4544	5542.0
Food residue	915	868	66.89	10.43	455	335.4
Consumed	10863	10280	844.9	140.75	4088	5206.6
Faeces	5880	5444	589.7	87.02	2169	2597.8
Digested	4983	4837	255.2	53.74	1919	2608.8
% Digestibility	45.87	47.05	30.20	38.29	46.95	50.11
Overall Digestibility	43.32	44.84	27.72	29.85	44.86	48.01

Experiment III Digestibility of dried bracken by Galloway bullock at Bush

	D:M.	Org.M.	C.P.	E.E.	C.F.	N.F.E.
Hay consumed	20304	19183	1445.67	241.614	7596.6	9900.15
% Diges. of hay consumed	54.03	56.06	35.93	41.96	63.66	52.43
Faecal residue from hay consumed	9331.9	8427.6	926.40	140.22	2760.6	4709.46
Total faeces	18100	16662	1806.5	289.o	6530.5	8033.8
Faecal residue from bracken consumed	8768.1	8234.4	880.1	148.9	3769.9	3324.4
Bracken consumed	11664	11064	1055.9	170.7	4277.6	5558.5
Digested from bracken	2895.9	2830.2	175.8	21.78	507.70	2234.2
% Diges. of bracken constituents	24.8	25.6	16.7	12.77	11.87	40.19

Experiment IV — Digestibility of Lothian Seeds Hay by Bullocks

Bullock No. 1

Period	Dates: Feeding	Dates: Faecal Collection	No. of Days	Food - fed: Fresh Wt.	Food - fed: Dry Wt.	Food Residues: Dry Wt.	Food Consumed: Dry Wt.	Faeces: Fresh Wt.	Faeces: Dry Wt.
I	19.6.48-22.6.48	21.6.48-24.6.48	4	24,000	20,760	215	20545	56725	7600
II	23.6.48-26.6.48	25.6.48-28.6.48	4	24,000	20,760	325	20435	55380	8620
III	27.6.48-30.6.48	29.6.48-2.7.48	4	24,000	20,760	260	20500	58520	9060

Bullock No. 2

Period	Dates: Feeding	Dates: Faecal Collection	No. of Days	Food - fed: Fresh Wt.	Food - fed: Dry Wt.	Food Residues: Dry Wt.	Food Consumed: Dry Wt.	Faeces: Fresh Wt.	Faeces: Dry Wt.
I	19.6.48-22.6.48	21.6.48-24.6.48	4	24,000	20,760	205	20555	51055	8000
II	23.6.48-26.6.48	25.6.48-28.6.48	4	24,000	20,760	300	20460	53275	7960
III	27.6.48-30.6.48	29.6.48-2.7.48	4	24,000	20,760	285	20475	53670	8360

Experiment IV

Analyses (% in dry matter)

Constituents	Hay Fed Periods I, II and III	Food Residue	Faeces Bullock I I	II	III	Faeces Bullock 2. I	II	III
Ash	7.91	-	12.40	12.86	12.62	12.50	12.77	12.25
Org. matter	92.09	-	87.6	87.14	87.38	87.50	87.23	87.75
Crude Protein	7.87	-	9.99	9.65	9.64	10.58	9.74	9.71
Ether Extract	2.08	-	2.11	1.97	1.94	2.18	1.90	2.01
Crude Fibre	39.46	-	29.20	29.90	29.05	29.79	29.04	29.85
N. F. E.	42.68	-	46.30	45.62	46.75	44.95	46.55	46.18

Experiment IV — Bullock No. 1

Period I.

	D.M.	Or.M.	C.P.	E.E.	C.F	N.F.E.
Hay fed	20760	19119.2	1633.9	431.82	8192.2	8860.7
Food Residue	215	198.0	16.9	4.47	84.8	91.8
Consumed	20545	18921.2	1617.0	427.35	8107.4	8768.9
Faeces	7600	6657.5	759.2	160.46	2219.2	3518.7
Digested	12945	12263.7	857.8	266.99	5888.2	5250.2
% Digestibility	63.01	64.82	53.05	53.12	72.63	59.87

Period II

Hay fed	20760	19119.2	1633.9	431.82	8192.2	8860.7
Food Residue	325	299.3	25.58	6.76	128.2	138.7
Consumed	20435	18819.9	1608.4	425.06	8064.0	8722.0
Faeces	8620	7511.6	831.8	169.8	2577.4	3932.3
Digested	11815	11308.3	776.6	255.25	5486.6	4789.7
% Digestibility	57.99	60.09	48.30	60.06	68.05	54.92

Period III

Hay fed	20760	19119.2	1633.4	431.82	8192.2	8860.7
Food Residue	260	239.4	20.46	5.41	102.6	110.9
Consumed	20500	18879.8	1613.5	426.41	8089.6	8749.8
Faeces	9060	7916.6	873.4	175.76	2631.9	4235.6
Digested	11440	10963.2	740.1	250.65	5457.7	4514.2
% Digestibility	55.81	58.08	45.87	58.78	67.47	51.60
Overall digestibility	58.94	61.00	49.07	57.32	69.38	55.46

Experiment IV Bullock No. 2

Period I.

	D.M.	Or. M.	C.P.	E.E.	C.F.	N.F.E.
Hay fed	20760	19119.2	1633.9	431.82	8192.2	8860.7
Food Residue	205	188.8	16.1	4.26	80.9	87.5
Consumed	20555	18930.4	1617.8	427.56	8111.3	8773.2
Faeces	8000	7000.0	846.3	174.42	2383.4	3596.1
Digested	12555	11930.4	771.5	253.14	5727.9	5177.2
% Digestibility	61.08	63.02	47.69	59.20	70.62	59.01

Period II

Hay fed	20760	19119.2	1633.9	431.82	8192.2	8860.7
Food residue	300	276.3	23.6	6.24	118.3	128.1
Consumed	20460	18842.9	1610.3	425.58	8073.8	8732.7
Faeces	7960	6943.7	775.3	151.24	2311.50	3705.4
Digested	12500	11899.2	835.0	274.34	5762.3	5027.3
% Digestibility	61.09	63.16	51.87	64.46	71.37	57.54

Period III

Hay fed	20760	19119.2	1633.9	431.82	8192.2	8860.7
Food Residue	285	262.5	22.43	5.93	112.5	121.7
Consumed	20475	18856.7	1611.5	425.89	8079.7	8739.1
Faeces	8360	7336.7	811.7	168.03	2495.7	3860.5
Digested	12115	11520.0	799.8	257.86	5584.0	4878.5
% Digestibility	59.18	61.08	49.62	60.56	69.11	55.83
Overall digestibility	60.45	62.42	49.73	61.41	70.37	57.46

Experiment V — Digestibility of Lothian Seeds Hay by Sheep

Sheep A

Period	Dates Feeding	Dates Faecal Collection	No. of days	Food Fed Fresh Wt.	Food Fed Dry Wt.	Food Residues. Fresh Wt.	Food Residues. Dry Wt.	Food Consumed Fresh Wt.	Food Consumed Dry Wt.	Faeces. Fresh Wt.	Faeces. Dry Wt.
I	19.6.48- 22.6.48	21.6.48- 24.6.48	4	4000	3440	915	685	3085	2755	4505	1560
II	23.6.48- 26.6.48	25.6.48- 28.6.48	4	4000	3440	480	335	3520	3105	4382	1540
III	27.6.48- 30.6.48	29.6.48- 2.7.48	4	4000	3440	520	315	3480	3125	4578	1620

Sheep B.

Period	Dates Feeding	Dates Faecal Collection	No. of days	Food Fed Fresh Wt.	Food Fed Dry Wt.	Food Residues. Fresh Wt.	Food Residues. Dry Wt.	Food Consumed Fresh Wt.	Food Consumed Dry Wt.	Faeces. Fresh Wt.	Faeces. Dry Wt.
I	19.6.48- 22.6.48	21.6.48- 24.6.48	4	4000	3440	355	275	3645	3165	4356	1630
II	23.6.48- 26.6.48	25.6.48- 28.6.48	4	4000	3440	321	215	3679	3225	4252	1530
III	27.6.48- 30.6.48	29.6.48- 2.7.48	4	4000	3440	390	275	3610	3165	4165	1560

Experiment V — **Analyses (% in dry matter)**

Constituents	Hay Fed I, II, III A and B	Food Residue I, II, III A.	Food Residue I, II, III B	Faeces A I	Faeces A II	Faeces A III	Faeces B I	Faeces B II	Faeces B III
Ash	7.91	7.22	10.3	10.60	11.70	11.92	10.54	11.55	11.79
Org. Matter	92.09	92.78	89.7	89.40	88.30	88.08	89.46	88.45	88.21
Crude Protein	7.87	7.27	7.69	9.02	8.35	9.02	8.80	9.05	8.53
Ether Extract	2.08	1.42	1.26	1.69	1.70	1.87	1.96	1.74	1.82
Crude Fibre	39.46	41.06	39.00	31.42	32.32	30.96	34.59	32.29	31.50
N. F. E.	42.68	43.03	41.75	47.27	45.93	46.23	44.11	45.37	46.36

Experiment V — **Sheep A**

	D.M.	Or.M.	C.P.	E.E.	C.F.	N.F.E.
Hay fed	3440	3168.2	270.7	71.55	1357.4	1468.2
Food Residue	685	635.6	49.8	9.73	281.2	294.8
Consumed	2755	2532.5	220.9	61.83	1076.2	1173.5
Faeces	1560	1394.7	140.7	26.36	490.1	737.4
Digested	1195	1137.8	80.23	35.41	586.1	436.1
% Digestibility	43.38	44.95	36.33	57.35	54.48	37.17

Period II

Hay fed	3440	3168.0	270.7	71.55	1357.5	1468.2
Food Residue	335	310.8	24.3	4.76	137.6	144.1
Consumed	3105	2857.2	246.4	66.80	1219.9	1324.1
Faeces	1540	1359.8	128.6	26.18	497.7	707.3
Digested	1565	1497.3	117.8	40.62	722.2	616.7
% Digestibility	50.41	52.40	47.81	60.81	59.20	46.58

Period III

Hay fed	3440	3168.0	270.7	71.55	1357.5	1468.2
Food Residue	315	292.3	22.9	4.473	129.3	135.5
Consumed	3125	2875.8	247.8	67.08	1228.1	1332.6
Faeces	1620	1426.9	146.1	30.29	501.6	748.8
Digested	1505	1448.9	101.7	36.79	726.5	583.8
% Digestibility	48.16	50.39	41.04	54.85	59.16	43.79

Experiment V Sheep B

	D.M.	Or. M. Or. M.	C.P.	E.E.	C.F.	N.F.E.
Hay fed	3440	3168.0	270.7	71.55	1357.5	1468.2
Food Residue	275	246.7	21.2	3.46	107.3	114.8
Consumed	3165	2921.4	249.6	68.08	1250.2	1353.4
Faeces	1630	1458.3	143.5	31.95	563.8	718.9
Digested	1535	1463.1	106.1	36.14	686.44	634.4
% Digestibility	48.50	50.08	42.5	53.08	54.88	46.89

Period II

Hay fed	3440	3168.0	270.7	71.55	1357.5	1468.2
Food Residue	215	192.9	16.5	2.71	83.9	89.8
Consumed	3225	2975.2	254.2	68.86	1273.6	1378.4
Faeces	1530	1353.3	138.6	26.62	494.0	694.2
Digested	1695	1621.9	115.8	42.22	779.6	684.3
% Digestibility	52.57	54.51	45.51	61.33	61.19	49.66

Period III

Hay fed	3440	3168.0	270.7	71.55	1357.5	1468.2
Food Residue	275	246.7	21.15	3.47	107.3	114.8
Consumed	3165	2921.4	249.6	68.09	1250.2	1353.4
Faeces	1560	1376.0	249.6	28.39	491.4	723.2
Digested	1605	1545.3	116.5	39.69	758.8	630.2
% Digestibility	50.71	52.89	46.68	58.30	60.70	46.58

Experiment V — Digestibility of hay. Sheep A

	Dry matter	Org. matter	C.Protein	E. Ext.	C.Fibre	N.F.E.
Total Consumption	8985	8265.43	715.1½	195.699	3524.24	3830.16
Total Faeces	4720	4181.40	415.41	82.838	1489.45	2193.57
Digested	4265	4084.03	299.73	112.861	2034.79	1636.59
% Digestibility	47.47	49.41	41.91	57.69	57.74	42.75
			Sheep B			
Total consumption	9555	8817.87	753.35	205.017	3774.03	4085.20
Total faeces	4720	4187.58	414.99	86.962	1554.49	2136.32
Digested	4835	4630.29	338.36	118.055	2219.54	1948.88
% Digestibility	50.60	52.51	44.92	57.56	58.83	47.71

Experiment VI — Digestibility of Green Bracken and Hay by Bullocks in July.

Bullock No. I

Period	Dates. Feeding	Faecal Collection	No. of days	Food Fed. Fresh Wt. B	Food Fed. Fresh Wt. H	Food Fed. Dry Wt. B	Food Fed. Dry Wt. H	Food Residues Dry Wt. B	Food Residues Dry Wt. H	Food Consumed Dry Wt. H	Food Consumed Dry Wt. B	Faeces Fresh Wt.	Faeces Dry Wt.
I	13.7.48-16.7.48	15.7.48-18.7.48	4	72000	12000	17280	10440	402	Nil	10440	16878	76810	11300
II	17.7.48-20.7.48	19.7.48-22.7.48	4	72000	12000	16776	10440	570	Nil	10440	16206	71755	10940
III	21.7.48-24.7.48	23.7.48-26.7.48	4	72000	12000	18000	10440	1200	Nil	10440	16800	80250	11620

Bullock No. 2

I	13.7.48-16.7.48	15.7.48-18.7.48	4	72000	12000	17280	10440	570	Nil	10440	16710	76745	10980
II	17.7.48-16.7.48	15.7.48-18.7.48	4	72000	12000	16776	10440	1450	Nil	10440	15326	74710	11080
III	21.7.48-24.7.48	23.7.48-26.7.48	4	72000	12000	18000	10440	1800	Nil	10440	16200	74950	11260

Expt VI

Analyses (% in dry matter).

Constituents	Hay Fed.	Bullock 1 & 2 Bracken Fed			Bullock 1 Food Residue			Bullock 1 Faeces			Bullock 2 Food Residue			Bullock 2 Faeces		
		I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
Ash	7,91	6.05	6.33	6.16	5.42	5.18	5.37	10.31	10.06	9.79	5.70	5.50	5.28	10.28	10.36	10.04
Org. M.	92.09	93.95	93.67	93.84	94.58	94.82	94.63	89.69	89.94	90.21	94.30	94.50	94.72	89.72	89.64	89.96
C. Prot.	7.87	13.91	15.30	12.82	7.18	5.83	5.99	15.61	16.24	16.47	8.09	4.26	6.14	15.28	15.18	15.8
E. Extract	2.08	2.86	2.94	2.83	2.06	1.80	1.33	3.07	3.03	3.56	1.80	2.58	1.81	2.46	2.60	2.85
C. Fibre	39.46	23.61	27.35	30.73	56.78	60.88	61.28	28.61	29.59	29.44	53.47	56.44	60.75	35.88	29.28	29.2
N.F.E.	42.68	53.57	48.08	47.46	28.56	26.31	26.03	42.40	41.08	40.74	30.94	31.22	26.02	36.10	42.58	42.0

Experiment VI — Bullock No. 1

Period I

	D.M.	Or.M.	C.P.	E.E.	C.F.	N.F.E.
Hay fed	10440	1614.2	821.7	217.17	4119.9	4456.0
Bracken fed	17280	16234.5	2403.7	494.21	4079.9	9256.8
Total fed	27720	25848.7	3225.4	711.38	8199.8	13712.8
Food Residue	402	380.2	28.86	8.28	228.3	114.8
Consumed	27318	25468.5	3196.5	703.10	7971.6	13597.9
Faeces	11300	10135.7	1763.9	346.92	3232.9	4791.36
Digested	16018	15332.8	1432.6	356.18	4738.7	8806.61
% Digestibility	58.64	60.19	44.82	50.65	59.44	64.75

Period II

Hay fed	10440	9614.2	821.7	217.17	4119.9	4456.0
Bracken fed	16776	15715.0	2566.8	493.28	4588.3	8066.8
Total fed	27216	25329.2	3388.5	710.45	8708.3	12522.8
Food Residue	570	540.5	33.2	10.26	347.1	149.96
Consumed	26646	24788.7	3355.2	700.19	8361.2	12372.9
Faeces	10940	9840.1	1776.7	331.52	3237.4	4494.8
Digested	15706	14948.6	1578.5	368.67	5123.8	7878.1
% Digestibility	58.98	60.31	47.04	52.65	61.20	63.67

Period III

Hay fed	10440	9614.2	821.67	217.17	4119.9	4456.0
Bracken fed	18000	16890.9	2307.5	509.45	5531.5	8542.9
Total fed	28440	26505.1	3129.2	726.62	9651.5	12998.9
Food Residue	1200	1135.5	71.9	15.96	735.4	312.35
Consumed	27240	25369.6	3057.3	710.7	8916.1	12686.6
Faeces	11620	10483.0	1913.9	413.7	3430.9	4733.9
Digested	15620	14886.6	1143.4	296.95	5495.2	7952.6
% Digestibility	57.35	58.68	37.39	41.78	61.63	62.66
Overall Digestibility	58.3	59.7	43.08	48.36	60.8	63.7

Experiment VI — Bullock No. 2

Period I

	D.M.	Or.M.	C.P.	E.E.	C.F.	N.F.E.
Hay fed	10440	9614.2	821.7	217.17	4119.9	4456.0
Bracken fed	17280	16234.5	2403.7	494.21	4079.9	9256.8
Total fed	27720	25878.7	3225.4	711.38	8199.8	13712.8
Food Residue	570	532.4	46.1	10.26	304.8	176.4
Consumed	27150	25316.3	3179.3	701.12	7895.1	13536.4
Faeces	10980	9852.6	1678.0	270.15	3940.2	3964.33
Digested	16170	15463.7	1501.3	430.97	3954.9	9572.09
% Digestibility	59.56	61.07	47.21	61.47	50.09	70.72

Period II

	D.M.	Or.M.	C.P.	E.E.	C.F.	N.F.E.
Hay fed	10440	9614.2	821.7	217.17	4119.9	4456.0
Bracken fed	16776	15715.0	2566.8	493.28	4588.3	8066.8
Total fed	27216	25329.2	3388.5	710.45	8708.3	12522.8
Food Residue	1450	1370.2	61.8	37.41	818.4	452.7
Consumed	25766	23959.0	3326.7	673.04	7889.89	12070.1
Faeces	11080	9930.6	1681.7	288.03	3243.4	4717.40
Digested	14686	14028.4	1645.1	385.01	4646.5	7352.7
% Digestibility	56.99	58.55	49.44	57.21	58.88	60.93

Period III

	D.M.	Or.M.	C.P.	E.E.	C.F.	N.F.E.
Hay fed	10440	9614.2	821.7	217.17	4119.9	4456.0
Bracken fed	18000	16890.9	2307.5	509.45	5531.5	8542.9
Total fed	28440	26505.1	3129.2	726.62	9651.5	13998.9
Food residue	1800	1705.0	110.5	32.58	1093.45	468.4
Consumed	26640	24800.1	3018.7	694.04	8558.0	12530.6
Faeces	11260	10130.1	1788.2	320.91	3289.30	4731.38
Digested	15380	14669.9	1230.4	373.13	5268.7	7799.2
% Digestibility	57.73	59.15	40.74	53.77	61.57	62.25
Overall Digestibility	58.1	59.6	45.8	57.5	56.8	64.6

Experiment VI

Digestibility of Bracken (July)

Bullock No. 1.

Hay consumed	31320	28820	2465.0	651.48	12359	13369
% Digestibility of hay consumed	58.94	61.00	49.07	57.32	69.38	55.46
Faecal Residue from hay consumed	12859.9	11241	1255.4	277.84	3785.3	955.2
Total Faeces	33860	30458.8	5454.58	1092.15	9891.22	14020.08
Faecal residue from bracken consumed	21001.1	19217.8	4199.18	814.31	6105.92	8064.88
Bracken consumed	49884	46784.16	7144.08	1462.44	12889.04	25289.35
Digested from Br.	28883.9	27566.36	2944.90	648.13	6783.12	17224.47
% Digestibility of Bracken constituents	57.90	58.94	41.23	44.33	52.61	68.09

Experiment VI — Digestibility of bracken (July)

Bullock No. 2

Hay consumed	31320	28820	2465.0	651.48	12359	13369
% Digestibility of hay consumed	60.45	62.42	49.73	61.41	70.37	57.46
Faecal Residue from hay consumed	12388	10832	1238.8	251.19	3662.7	5687.2
Total faeces	33320	29913.3	5147.89	879.09	10472.88	13413.11
Faecal residue from bracken consumed	20932	19081.3	3909.09	627.90	6810.18	7725.91
Bracken consumed	48236	45232.76	7059.61	1416.69	11983.10	24769.06
Digested from bracken	27304	26151.46	3150.52	788.79	5172.92	17043.15
% Digestibility of bracken constituents	56.60	57.81	44.64	55.67	43.17	68.79

Experiment VII — Digestibility of Green bracken in July, by Sheep at Buckholm.

Sheep A

Period	Dates. Feeding	Faecal Collection	No. of days	Food Fed Fresh Wt.	Food Fed Dry Wt.	Food Residues Fresh Wt.	Food Residues Dry Wt.	Food Consumed Dry Wt.	Faeces. Fresh Wt.	Faeces. Dry Wt
I	13.7.48-16.7.48	15.7.48-18.7.48	4	16000	3840	1650	510	3330	6437	1490
II	17.7.48-20.7.48	19.7.48-22.7.48	4	16000	3728	2150	1070	2658	6105	1370
III	21.7.48-24.7.48	23.7.48-26.7.48	4	16000	4000	3550	1480	2520	6260	1300

Sheep B

Period	Dates. Feeding	Faecal Collection	No. of days	Food Fed Fresh Wt.	Food Fed Dry Wt.	Food Residues Fresh Wt.	Food Residues Dry Wt.	Food Consumed Dry Wt.	Faeces. Fresh Wt.	Faeces. Dry Wt
I	13.7.48-16.7.48	15.7.48-18.7.48	4	16000	3840	1875	530	3310	4365	1290
II	17.7.48-20.7.48	19.7.48-22.7.48	4	16000	3728	3050	710	3018	3942	1180
III	21.7.48-24.7.48	23.7.48-26.7.48	4	16000	4000	3310	1150	2850	4285	1390

Experiment VII

Analyses (% in dry matter)

	Green Bracken fed.			Food Residue Sheep B			Faeces Sheep B			Food Residue Sheep A			Faeces Sheep A		
	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
Ash	6.05	6.33	6.16	6.71	5.90	6.09	8.26	8.18	8.25	5.74	6.37	5.16	9.43	9.07	9.37
Or.M.	93.95	93.67	93.84	93.29	94.10	93.91	91.74	91.82	91.75	94.26	93.63	94.84	90.57	90.93	90.63
C. Prot	13.91	15.30	12.82	13.71	10.51	13.15	20.04	19.52	19.06	9.68	13.94	9.36	20.99	22.06	20.41
E. Ext.	2.86	2.94	2.83	2.52	2.84	2.57	2.69	2.42	2.72	2.47	2.72	2.35	2.27	3.06	2.56
C. Fibre.	23.61	27.35	30.73	38.91	44.85	40.17	27.92	30.10	30.10	45.50	34.44	35.54	25.25	25.39	25.55
N. F. E.	53.57	48.08	47.46	38.15	35.9	38.02	41.09	39.78	39.87	36.61	42.53	37.59	42.06	40.42	42.11

Experiment VII. Sheep A

Period I

	D.M.	Or.M.	C.P.	E.E.	C.F.	N.F.E.
Bracken fed	3840	3607.7	534.1	109.83	906.6	2057.1
Total fed	3840	3607.7	534.1	109.83	906.6	2057.1
Food residue	510	480.7	49.4	12.60	232.1	186.8
Consumed	3330	3126.9	484.8	97.23	674.56	1870.4
Faeces	1490	1349.6	312.8	33.82	376.2	626.8
Digested	1840	1777.4	171.9	63.41	298.4	1243.7
% Digestibility	55.26	56.83	35.48	65.22	44.24	66.53

Period II

Bracken fed	3728	3492.2	570.4	109.61	1019.6	1792.4
Total fed	3728	3492.2	570.4	109.61	1019.6	1792.4
Food Residue	1070	1001.9	149.2	29.10	368.5	455.1
Consumed	2658	2490.3	421.2	80.51	651.1	1337.3
Faeces	1370	1245.7	302.2	41.92	347.8	553.8
Digested	1288	1244.6	119.0	38.59	303.2	783.6
% Digestibility	48.46	50.00	28.26	47.93	46.57	58.61

Period III

Bracken fed	4000	3753.2	512.8	113.22	1229.2	1898.4
Total fed	4000	3753.2	512.8	113.22	1229.2	1898.4
Food residue	1480	1403.6	138.5	34.78	673.9	556.3
Consumed	2520	2349.6	374.2	78.44	555.2	1342.1
Faeces	1300	1178.1	265.3	33.28	332.1	547.4
Digested	1220	1171.5	108.9	45.16	223.1	794.7
% Digestibility	48.42	49.88	29.09	57.57	40.19	59.23

Experiment VII — Sheep B

Period I

	D.M.	Or.M.	C.P.	E.E.	C.F.	N.F.E.
Bracken fed	3840	3607.7	534.1	109.83	906.6	2057.1
Total fed	3840	3607.7	534.1	109.83	906.6	2057.1
Food residue	530	494.4	72.7	13.36	206.2	202.2
Consumed	3310	3113.2	461.5	96.47	700.4	1854.9
Faeces	1290	1183.4	258.5	34.70	360.2	530.1
Digested	2020	1929.8	202.9	61.77	340.2	1324.9
% Digestibility	61.02	62.00	43.96	64.03	48.57	71.43

Period II

Bracken fed	3728	3492.2	570.4	109.61	1019.6	1792.4
Total fed	3728	3492.2	570.4	109.61	1019.6	1792.4
Food residue	710	668.2	74.63	20.17	318.4	254.9
Consumed	3018	2824.0	495.77	89.44	701.1	1537.5
Faeces	1180	1083.4	230.35	28.56	355.2	469.4
Digested	1838	1740.6	265.42	60.88	345.9	1068.1
% Digestibility	60.90	61.66	53.53	68.08	49.35	69.44

Period III

Bracken fed	4000	3753.2	512.79	113.22	1229.2	1898.4
Total fed	4000	3753.2	512.79	113.22	1229.2	1898.4
Food residue	1150	1080.0	151.22	29.56	461.9	437.2
Consumed	2850	2673.2	361.57	83.66	767.2	1461.2
Faeces	1390	1275.4	264.92	37.81	418.4	554.2
Digested	1460	1397.8	96.65	45.85	348.8	907.0
% Digestibility	51.23	52.30	26.73	54.80	45.58	60.67

Experiment VII — Digestibility of Bracken in July

Sheep A

		D.M.	Or.M.	C.P.	E.E.	C.F.	N.F.E.
Total consumed	I,II and III	8508	7966.82	1280.24	256.18	1880.81	4549.84
Total faeces	I,II and III	4160	3773.31	880.32	109.02	1056.17	1727.90
Total digested	I,II and III	4348	4193.51	399.92	147.16	824.64	2821.94
% Digestibility		51.11	52.64	31.25	57.45	43.84	62.02

Sheep B

Total consumed	I,II and III	9178	8610.41	1318.80	269.57	2168.75	4853.62
Total faeces	I,II and III	3860	3542.20	753.80	101.07	1133.75	1553.66
Total digested	I,II and III	5318	5068.21	565.00	168.50	1035.00	3299.96
% Digestibility		57.94	58.86	42.84	62.50	47.72	68.00

Experiment VIII — Digestibility of Green Bracken in August

Bullock No. 1

Period	Dates. Feeding	Faecal Collection	No. of days	Foodfed Fresh Brack.	Wt. Hay	Dry Brack	Wt. Hay	Food Res. Dry Brack	Wt. Hay	Food consumed Dry Brack.	Wt. Hay	Faeces Fresh Wt.	Dry Wt.
I	19.8.48-22.8.48	21.8.48-24.8.48	4	68,000	12000	20248	10560	4526	Nil.	15722	10560	75130	10060
II	23.8.48-26.8.48	25.8.48-28.8.48	4	59,000	12000	14820	10560	3590	Nil.	11230	10560	46610	9920
III	27.8.48-30.8.48	29.8.48-1.9.48	4	42,000	12000	12680	10560	2904	Nil.	9776	10560	76280	10440

Bullock No. 2.

Period	Dates. Feeding	Faecal Collection	No. of days	Foodfed Fresh Brack.	Wt. Hay	Dry Brack	Wt. Hay	Food Res. Dry Brack	Wt. Hay	Food consumed Dry Brack.	Wt. Hay	Faeces Fresh Wt.	Dry Wt.
I	19.8.48-22.8.48	21.8.48-24.8.48	4	72,000	12000	21528	10560	4048	Nil.	17480	10560	83530	12320
II	23.8.48-26.8.48	25.8.48-28.8.48	4	61,000	12000	17390	10560	3570	Nil.	13820	10560	76345	11720
III	27.8.48-30.8.48	29.8.48-1.9.48	4	60,000	12000	17880	10560	2604	Nil.	15276	10560	78640	11880

Experiment VIII

Analyses (% in dry matter)

	Hay	Green Bracken fed I	Green Bracken fed II	Green Bracken fed III	Food Res. Bull. 1 I	Food Res. Bull. 1 II	Food Res. Bull. 1 III	Food Res. Bull 2. I	Food Res. Bull 2. II	Food Res. Bull 2. III	Faeces Bull.1. I	Faeces Bull.1. II	Faeces Bull.1. III	Faeces Bull.2 I	Faeces Bull.2 II	Faeces Bull.2 III
Ash	7.91	5.63	5.24	5.92	5.53	5.51	6.98	4.06	3.98	6.73	9.90	9.68	9.71	9.99	9.19	9.29
Org. M.	92.09	94.37	94.76	94.08	94.47	94.49	93.02	95.94	96.02	93.27	90.10	90.32	90.29	90.01	90.81	90.7
C. Prot.	7.87	10.50	8.98	8.80	6.78	7.11	8.89	6.81	5.77	5.00	15.19	14.64	13.09	14.52	14.62	14.2
E. Ext.	2.08	2.08	2.62	2.81	1.98	1.61	2.87	1.16	1.28	1.95	1.69	1.83	1.48	1.72	1.15	1.52
C. Fibre	39.46	34.71	36.40	35.48	54.01	46.57	40.38	57.67	55.32	55.78	35.88	31.62	34.91	31.15	30.54	305
N.F.E.	42.68	47.08	46.76	46.99	31.70	39.20	40.88	30.30.	33.65	30.54	37.34	42.23	40.81	42.62	44.50	44.6

Experiment VIII — Bullock No. 1.

Period I

	D.M.	Or.M.	C.P.	E.E.	C.F.	N.F.E.
Hay fed	10560	8723;34	830.98	219.62	41[illegible]6.36	4506.52
Bracken fed	20248	19108.00	2125.89	420.15	7027.98	9532.30
Total fed	30808	28831.34	2956.87	639.78	11194.3	14038.8
Food residue	4526	4275.60	306.86	89.61	2444.4	1434.7
Consumed	26282	24555.7	2650.01	550.16	8749.8	12604.09
Faeces	10060	9062.8	1527.88	169.99	3609.1	3755.8
Digested	16222	15492.99	1122.13	380.17	5140.8	8848.20
% Digestibility	61.72	63.08	42.34	69.10	58.75	70.23

Period II

Hay fed	10560	9723.34	830.98	219.63	4166.36	4506.52
Bracken fed	14820	14043.6	1330.89	388.28	5394.63	6930.08
Total fed	25380	23766.9	2161.87	607.91	9560.99	11436.60
Food residue	3590	3392.2	255.25	57.80	1671.85	1407.26
Consumed	21790	20374.7	1906.62	550.11	7889.14	10029.34
Faeces	9920	8959.80	1452.23	181.53	3136.78	4189.19
Digested	11870	11414.91	454.39	368.59	4752.36	5840.15
% Digestibility	54.48	56.01	23.83	67.00	60.23	58.22

Period III

Hay fed	10560	9723.34	830.98	219.63	4166.36	4506.52
Bracken fed	12680	11928.50	115.78	356.29	4498.53	5958.00
Total fed	23240	21651.84	1946.76	575.92	8664.89	10464.52
Food residue	2904	2701.18	258.16	83.35	1172.66	1187.23
Consumed	20336	18950.66	1688.60	492.57	7492.23	9277.29
Faeces	10440	9426.92	1336.56	154.52	3645.06	4260.90
Digested	9896	9523.74	352.04	338.05	3847.17	5016.39
% Digestibility	48.65	50.26	20.84	68.61	51.35	54.07
Overall Digestibility	55.00	56.5	29.00	68.20	56.80	60.80

Experiment VIII — Bullock No. 2

Period I

	D.M.	Org.M.	Cr. Pr.	E E	Cr. Fibre	N F E
Hay fed	10560	9723.34	830.98	219.63	4166.36	4506.52
Bracken fed	21528	20315.90	2260.40	447.78	7472.61	10135.95
Total fed	32088	30039.24	3091.38	667.41	11638.97	14642.47
Food residue	4048	3883.65	275.67	46.96	2334.58	1226.52
Consumed	28040	26155.6	2815.71	620.45	9304.39	13415.95
Faeces	12320	11089.3	1788.93	211.914	3837.72	5250.87
Digested	15720	15066.3	1026.78	408.538	5466.67	8156.08
% Digestibility	56.07	57.61	36.47	65.84	58.76	60.84

Period II

Hay fed	10560	9723.34	830.98	219.63	4166.36	4506.52
Bracken fed	17390	16479.90	1561.80	455.63	6330.29	8132.10
Total fed	27950	26203.24	2392.78	675.257	10496.6	12638.62
Food residue	3570	3427.94	205.99	45.69	1974.97	1201.26
Consumed	24380	22775.30	2186.79	629.56	8521.68	11437.36
Faeces	11720	10642.70	1713.08	134.78	3579.30	5215.38
Digested	12660	12132.60	473.71	494.78	4942.38	6221.98
% Digestibility	51.93	53.25	21.66	78.60	58.00	54.39

Period III

Hay fed	10560	9723.34	830.98	219.63	4166.36	4506.52
Bracken fed	17880	16822.1	1573.52	502.45	6343.98	8402.15
Total fed	28440	26545.5	2404.50	722.07	10510.34	12908.67
Food residue	2604	2428.7	130.20	50.77	1452.47	795.26
Consumed	25836	24116.8	2274.30	671.30	9057.87	12113.41
Faeces	11880	10778.0	1683.45	180.58	3619.98	5292.90
Digested	13956	13338.75	590.85	490.71	5437.89	6820.51
% Digestibility	54.03	55.31	25.98	73.10	60.05	56.33
Overall Digestibility	54.0	55.4	28.0	72.5	58.9	57.2

Experiment VIII — Digestibility of Bracken in August

Bullock No. 1

	D.M.	Org.M.	C. Prot.	E. Ext.	C. Fibre	N. F. E.
Hay consumed	31680	29170.02	2492.94	658.878	12499.08	13519.56
% Dig. of hay consumed	58.94	61.00	49.07	57.32	69.38	55.46
Faecal residue from hay cons.	13008	11376	126918	281.25	3827.4	6021.3
Total faeces	30420	27449.47	4316.67	506.039	10390.94	12205.98
Faecal residue from Br. cons.	17412	16073.47	3046.87	224.789	6563.54	6184.68
Bracken consumed	36728	34711.09	3752.29	933.964	11632.18	18391.16
Digest.from bracken	19316	18637.62	705.42	709.175	5068.64	12206.48
% Dig. of bracken constituents	52.60	53.70	18.80	75.93	43.55	66.39

Bullock No. 2

Hay consumed	31680	29170.02	2492.94	658.878	12499.08	13519.56
% Dig. of hay consumed	60.45	62.42	49.73	61.41	70.37	57.46
Faecal residue from hay cons.	12529	10963	1253.1	254.28	3703.4	5751.7
Total faeces	35920	32510.00	5185.46	527.276	11037.0	15759.15
Faecal residue from Br. cons.	23391	21547	3932.36	272.996	7333.6	10007.45
Bracken consumed	46576	43877.62	4783.86	1262.431	14384.86	23447.16
Digested from Bracken	23185	22330.62	851.50	989.435	7051.26	13439.71
% dig. of bracken constituents	49.79	50.886	17.80	78.40	49.04	57.32

Experiment IX — Digestibility of Green Bracken in August.

Period	Dates Feeding	Dates Faecal Collection	No. of days	Food Fed. Bracken Fresh Wt.	Food Fed. Bracken Dry Wt.	Food Residues Dry Wt.	Food Consumed Dry Wt.	Faeces. Fresh Wt.	Faeces. Dry Wt.
				Sheep A					
I	19.8.48-22.8.48	21.8.48-24.8.48	4	16000	4784	1530	3254	5487	1870
II	23.8.48-26.8.48	25.8.48-28.8.48	4	10000	2825	800	2025	3823	1160
III	27.8.48-30.8.48	29.8.48-1.9.48	4	9000	2704	910	1794	3509	1130
				Sheep B					
I	19.8.48-22.8.48	21.8.48-24.8.48	4	16000	4784	1560	3224	5055	1520
II	23.8.48-26.8.48	25.8.48-28.8.48	4 m	14000	4005	1900	2105	4540	1320
III	27.8.48-30.8.48	29.8.48-1.9.48	4	12000	3636	1340ø	2296	3650	1160

Experiment IX

Analyses (% in dry matter)

	Green Br. Fed.			Residue Sheep B			Residue Sheep A			Faeces Sheep B			Faeces Sheep A		
	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
Ash	5.63	5.24	5.92	4.34	4.13	6.02	6.57	5.80	4.95	8.00	7.34	7.50	9.06	7.47	7.09
Or.M.	94.37	94.76	94.08	95.66	95.87	93.98	93.43	94.20	95.05	92.00	92.66	92.50	90.94	92.53	92.91
C.P.	10.50	8.98	8.80	8.02	7.46	8.02	8.13	7.90	7.31	15.10	15.75	14.88	16.63	17.03	16.58
E. E.	2.08	2.62	2.81	1.39	1.18	1.61	1.20	1.30	1.19	1.41	1.31	1.30	1.66	1.33	1.52
C. F.	34.71	36.40	35.48	41.58	39.92	38.53	44.48	45.35	41.05	31.59	33.78	33.31	28.53	30.66	31.30
N.F.E.	47.08	46.76	46.99	44.67	47.31	45.82	39.62	39.65	45.5	43.9	41.82	43.01	44.12	43.51	43.51

Experiment IX — Sheep A

Period I

	D.M.	Or.M.	C.P.	E.E.	C.F.	N.F.E.
Bracken Fed	4784	4514.6	502.3	99.50	1660.6	2252.3
Total fed	4784	4514.6	502.3	99.50	1660.6	2252.3
Food Residue	1530	1429.5	124.4	18.36	680.5	606.2
Consumed	3254	3085.2	377.9	81.15	980.1	1646.1
Faeces	1270	1154.9	211.2	21.08	362.3	560.3
Digested	1984	1930.2	166.8	60.06	617.7	1085.8
% Digestibility	60.97	62.56	44.14	74.01	63.02	65.98

Period II

Bracken fed	2825	2676.9	253.7	74.01	1028.2	1321.1
Total fed	2825	2676.9	253.7	74.01	1028.2	1321.1
Food residue	800	753.6	63.2	10.40	362.8	317.2
Consumed	2025	1923.3	190.5	63.62	665.4	1003.8
Faeces	1160	1073.4	197.6	15.43	355.6	504.8
Digested	865	849.9	- 7.1	48.19	309.8	499.1
% Digestibility	42.72	44.20	- 3.72	75.75	46.56	49.66

Period III

Bracken fed	2704	2543.8	237.9	75.98	959.4	1270.6
Total fed	2704	2543.8	237.9	75.98	959.4	1270.6
Food Residue	910	864.9	66.5	10.83	373.6	414.1
Consumed	1794	1678.9	171.4	65.15	585.8	856.6
Faeces	1130	1049.8	187.3	17.18	353.7	491.7
Digested	664	629.1	-15.9	47.98	232.1	364.8
% Digestibility	36.99	37.47	-9.28	73.66	39.62	42.59

Experiment IX — Sheep B

Period I

	D.M.	Org.M.	Cv.Pr.	E.Ext	Cv.Fibre	NFE
Bracken fed	4784	4514.6	502.3	99.51	1660.6	2252.3
Total fed	4784	4514.6	502.3	99.51	1660.6	2252.3
Food Residue	1560	1492.4	125.1	21.68	648.7	696.8
Consumed	3224	3022.2	377.2	77.82	1011.9	1555.5
Faeces	1520	1398.4	229.5	21.43	480.2	667.3
Digested	1704	1623.8	147.7	56.39	531.8	888.2
% Digestibility	52.86	53.74	39.16	72.46	52.55	57.12

Period II

Bracken fed	4005	3795.1	359.7	104.93	1457.9	1872.8
Total fed	4005	3795.1	359.7	104.93	1457.9	1872.8
Food Residue	1900	1821.6	141.7	22.43	758.5	898.9
Consumed	2105	1973.5	217.9	82.51	699.4	973.8
Faeces	1320	1223.1	207.9	17.29	445.9	552.0
Digested	785	750.4	10.0	65.22	253.5	421.8
% Digestibility	37.29	38.04	4.60	79.05	36.34	43.31

Period III

Bracken fed	3636	3420.8	319.9	102.17	1290.0	1708.6
Food Residue	1340	1259.4	107.5	21.58	516.3	613.9
Consumed	2296	2161.4	212.5	80.59	773.7	1094.6
Faeces	1160	1073.0	172.6	15.08	386.1	498.9
Digested	1136	1088.4	39.9	65.51	387.3	595.7
% Digestibility	49.48	50.35	18.77	81.28	50.06	54.40

Experiment IX — Digestibility of bracken (August) by Sheep

Sheep A

	D.M.	Org.M.	Cr. Pr.	E.E.	Cr.Fibre	NFE
Total Consumption I, II and III	7073	6687.38	739.84	209.913	2231.27	3506.54
Total Faeces I, II and III	3560	3278.15	596.08	53.688	1071.66	1556.81
Total Digested I, II and III	3513	3409.23	143.76	156.225	1159.61	1949.73
% Digestibility	49.67	50.98	19.44	74.40	52.00	55.60

Sheep B

Total Consumption I, II and III	7625	7157.14	807.61	240.923	2484.07	3623.96
Total faeces I, II and III	4000	3694.47	610.03	53.704	1312.46	1718.22
Total Digested I, II and III	3625	3462.67	197.58	187.219	1171.61	1905.74
% Digestibility	47.55	48.38	24.47	77.72	47.19	52.59

Plate I. Site of feeding Experiment, Stone-built pens: Hogg Hill, Buckholm, Galashiels

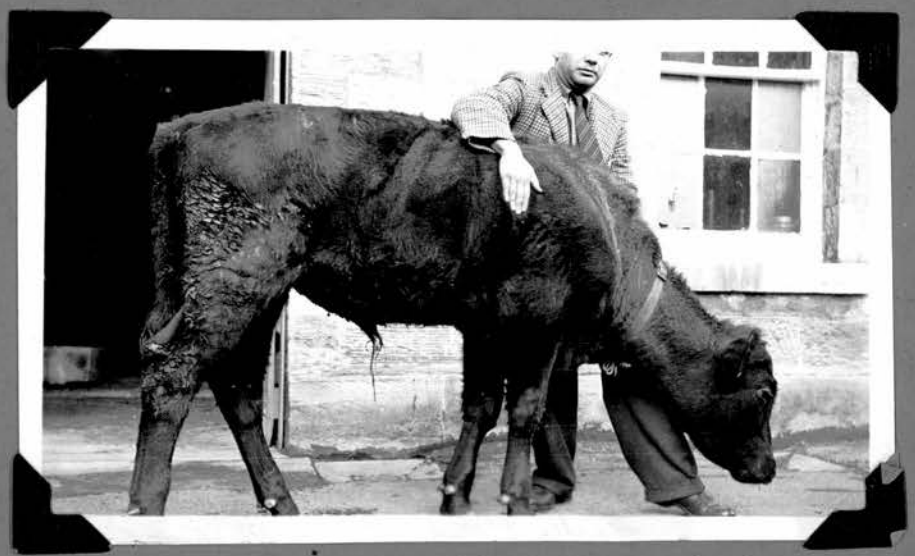

Plate II. Yearling Galloway bullock, 8 hours before death, at Bush Midlothian.

Plate III Pained facial appearance of Galloway bullock - 8 hours before death.

Plate IV. Blood and mucous discharges from nostrils, 8 hours before death: Galloway bullock.

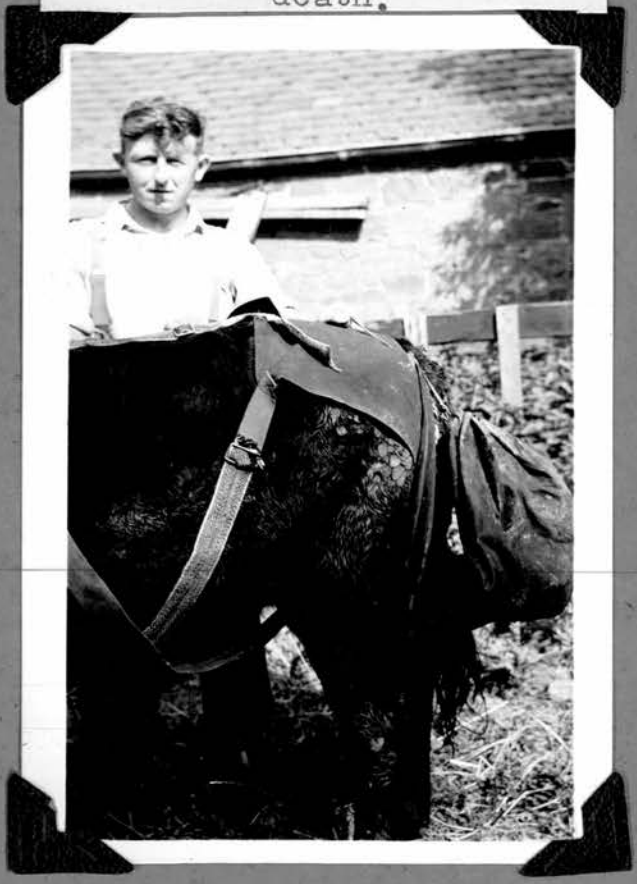

Plate V. Metabolic bag used in Digestibility Experiments.

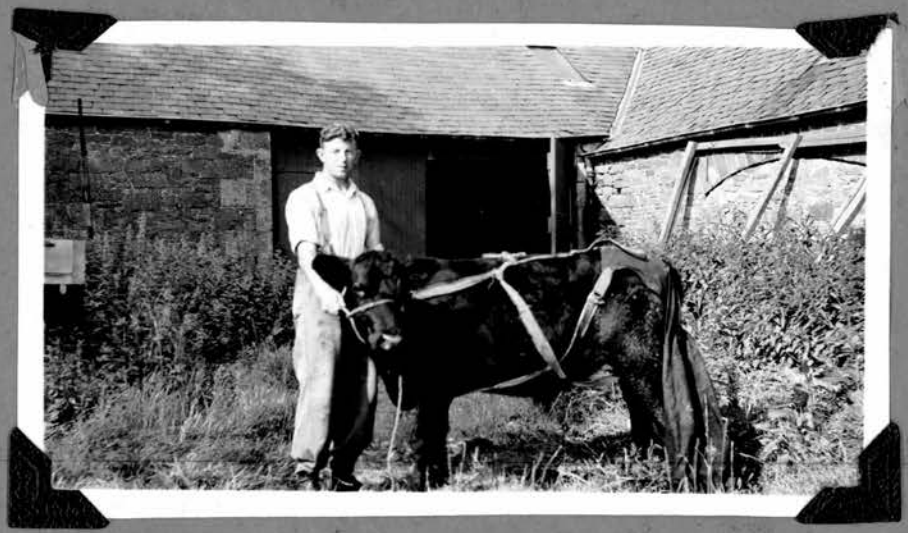

Plate VI. The metabolic harness in use.

Plate VII. The clotted blood streaks in the caecum of Animal No. 2 (Chapter II) giv-:ing an appearance of "Zebra-markings".

Plate VIII. Abomasum of animal No. 2 (vide Ch.II) showing ulceration and blood clots (dark spots).

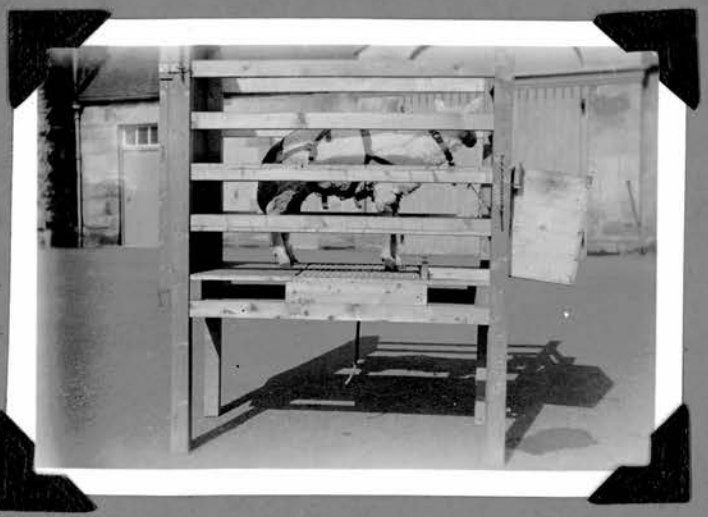

Plate IX. The metabolic cage for sheep. The urine is collected through the bottom tube.

Plate X. The arrangements in sheep metabolic cage with the door lowered for emptying the bag.

Plate XI. Metabolic bag with "zipp" fasteners.

Plate XII. The harness for attachment of faeces bag.